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INDEX ISSUE

METALS IN ENGINEERING

On the Quality of Leadership

THE ILLUSIVE QUALITY of leadership is referred to by some as an art, and by others as a science. But regardless of the words used to define it, leadership is the most vital factor in American industry. And a true definition of the word probably lies somewhere between the extremes of the exact sciences and the inexact arts. Perhaps leadership can best be described, rather than defined, as a quality of personality—the ability of one individual to influence others willingly to accept direction.

By any definition, leadership is a rare quality and where it is found in any area of human endeavor it should be carefully nurtured and cultivated. I believe this is especially true in the field of engineering. We constantly are searching for the man with the capacity to conceive new concepts, to initiate new processes, to strike out on his own initiative in directions to benefit himself and his employer—the man who is not afraid to quarrel with tradition. Whereas it has been said with some truth that the world of the future belongs to the scientists, it also is true that the engineer with initiative must, in the next generation as now, prove the scientists' theories. Looking ahead, therefore, we must be alert to identify and willing to encourage the kind of men who can fulfill the increasingly more strict requirements of engineering leadership.

This task is made especially difficult because we cannot even accurately define our terms. Nevertheless, experience has taught us to look for a few recognizable traits in a potential leader. They are:

1. Intelligence—the ability to think effectively, judge wisely and act decisively. People need to be mentally alert in order to succeed as industrial leaders.
2. The will to succeed. Industrial leaders are self starters and good finishers. They work long and hard. They are willing to accept the demands of success.
3. Managerial capacity. Real leaders want to lead. They seek, accept and faithfully discharge responsibility.
4. Effective human relations. Leaders study people and try to understand them. They train themselves in tolerance in order to deal effectively with people as individuals and in groups.

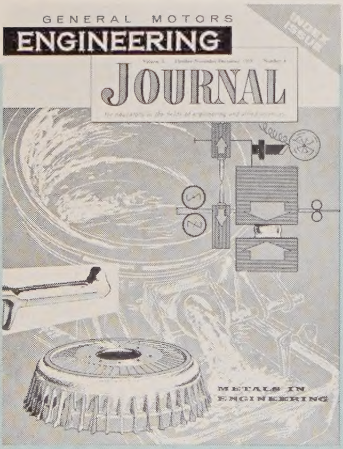
Certainly these are not the only qualities of leadership. There are other undefinables such as character, integrity and personality. Put them all together and you have an ideal leader. Most men fall considerably short of the ideal. But in their constant striving for personal improvement, they expand their minds and in the process raise the quality of their product.

As proof of this we only need to look back on the history of any successful institution. With the right kind of leadership, such enterprises have expanded and created new opportunities. For instance, General Motors now employs more engineers than ever before. We have engineers applying their skills in areas of engineering that were not even recognized a few years ago. What is more, this demand is increasing year by year as our product becomes more complex and our need for new and improved processes becomes more critical.

Today, we are making advances in science and engineering that were thought impossible just a few years ago. With adequate leadership this progress will compound itself in the years ahead. The need for sound leadership will expand and with it will expand opportunity for those men with the will and the skill to lead.

J E Goodman

James E. Goodman,
Vice President and
Group Executive



THE COVER

Metals long have been familiar and useful materials in the work of the engineer. His task is to understand them and to use them in their various forms for his design purposes.

In this issue's cover design, artist John A. Dickey depicts the engineer's understanding of metals with symbols for tension and compression tests, and for machining and rolling. Knowledge of metallurgy and the refining processes is suggested by the pouring ladle of an aluminum foundry. Some uses of metals in the automobile are represented by the finned aluminum brake drum and the plated steel bumper.

The back cover shows views of special porous bronze materials produced by Moraine Products Division for fuel and air filters, flame arrestors, gas diffusers, and other similar applications. One material (upper view) is produced from particles made by atomizing molten copper. The other material is made by cutting off equi-axed particles from copper wire and tumbling. In either case the particles are coated with tin, then heated in molds to bond them into strong porous bronze shapes.

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The Design and Operation of a Facility for Testing Aircraft Engine Anti-Icing Systems

By CHRISTIAN J. LITSCHER
and RICHARD M. GEORGE
Allison Division

Test facility simulates natural icing conditions

Fig. 1—Shown here is the Lockheed Electra Prop Jet Commercial Transport Aircraft, powered by four Allison Model 501-D13 engines with Aeroproducts propellers. Allison engineers developed an icing simulation test facility to test the effectiveness of the engine anti-icing system for this particular installation.

A build up of ice in the inlet air passages of a gas turbine engine can choke the air supply and cause engine failure. During the development of the Allison 501-D13 prop-jet engine for the Electra commercial aircraft, a question arose as to the effectiveness of the engine's anti-icing system. Existing test facilities at Allison were not capable of producing the simulated natural icing conditions needed for a complete study of the system. As a result, a test facility was designed and built which was capable of creating and controlling a simulated icing atmosphere over a wide range of operating conditions. To design the facility, Allison engineers made a thorough study of existing information on the characteristics of an icing atmosphere and also enlisted the aid of others experienced with icing studies in the aviation field. The test facility finally built served to prove that the anti-icing system for the Electra engine was entirely adequate. In addition, the facility is being used to conduct icing tests on other Allison gas turbine engines.

DEVELOPING a turbo-jet or prop-jet engine involves many hours of testing during which each component, as well as the complete engine, is compelled to prove its performance and endurance capabilities under almost every conceivable operating condition. The Allison Division model 501-D13 prop-jet engine, which propels the new commercial Electra aircraft (Fig. 1), was no exception. This engine model logged more than half a million hours of development and flight test time prior to its first commercial flight.

Throughout an engine development program, test data are analyzed, correlated, and studied carefully for any variation with design-anticipated performance. When even the slightest question on engine performance arises, it is given the most critical attention. Any reasonable doubt about operational safety or efficiency is dispelled through design improvements and subsequent re-testing.

During the development of the Electra engine, one of these performance questions arose—a question on engine anti-icing effectiveness.

Test Facility to Simulate Icing Conditions Was Needed

A build up of ice on the inlet air passages of a gas turbine engine limits the flow of vital combustion air to the engine. Such an ice build up can choke this air supply to the extent of causing engine failure.

To prevent an ice build up, an anti-icing system is used that feeds bleed air from the compressor section, at a temperature of 580°F and a pressure of 280 in. of mercury absolute, through passages in the engine inlet housing and inlet guide vanes. The air heats the exposed surfaces sufficiently to prevent freezing of supercooled water droplets. The aircraft inlet duct is heated in the same manner.

The effectiveness of an engine anti-icing system is rather difficult to prove. At the time of the Electra engine development program, very few testing facilities existed which could create and control their own icing atmospheres and accommodate large range, full scale icing tests.

At Allison Division, facilities were available for performing cold starting tests at temperatures down to −75°F; for performing hailstone tests wherein ice balls up to 3 inches in diameter are hurled into the engine inlet at speeds approaching 500 mph; and for ramming engines with refrigerated air at temperatures far below zero. None of these facilities, however, could simulate natural icing conditions.

For the Electra engine, as on previous Allison engines, icing tests were conducted in natural and simulated icing atmospheres at the U.S. Government-owned Mount Washington facility in New Hampshire. Also, the Electra engine was mounted in a test bed aircraft and flown through artificial clouds created by water sprayed at icing temperatures from a tanker aircraft. While these tests seemed to indicate adequate operation of the engine's anti-icing system, there still remained a question as to its effectiveness in certain areas of operation.

As a result, Allison decided to install its own ground testing facility which could create and control icing atmosphere over a wide variety of conditions. Data from tests run in this facility would either dispel any doubts about the effectiveness of the Electra engine's anti-icing system or would provide an excellent basis for design refinements.

The Test Facilities Design Department was consulted and assigned the project of providing the icing test facility.

Background Study Aided in Design of Test Facility

Before progress could be made toward an ultimate design of the icing test facility, design engineers assigned to the project had to obtain background information on the characteristics of an icing atmosphere—the components that comprise it and related phenomena of the aircraft icing process. On investigation, the engineers found a number of sources where information on the subject could be obtained (references 1 through 4). The principal point of the background study involved the investigation of cloud formation and its behavior.

Ice Crystal Clouds

At temperatures below the melting point of ice, two types of clouds exist—ice crystal clouds and supercooled clouds. Ice crystal clouds are composed of ice crystals so small that they seem to remain suspended in air, but actually are falling very slowly. This type of cloud is not the principal cause of hazardous aircraft icing. The ice crystals merely hit and carom off the surface, creating no significant problem other than electrostatic charges which can affect radio operation. The second type, supercooled clouds, are the villains.

Supercooled Clouds

Liquid drops can remain unfrozen at temperatures far below their freezing point. In fact, liquid water drops have been supercooled to —40°F, and below, without crystallizing. For the water droplets to freeze, a nucleating process must occur. This can happen in a number of ways. Since a supercooled liquid is unstable, the introduction of a crystal having the same or similar composition as the liquid will cause the crystal to grow at the liquid's expense, as long as the temperature remains below the melting point of the crystal.

Some types of crystals are more efficient nucleators than others but, with respect to supercooled-water clouds, almost any substance that is foreign to pure water can aid the nucleating process, the difference being only in degree. Thus, any small foreign particles present on the surface of the aircraft can initiate the process. Once the crystal has formed, it grows very rapidly, largely due to the supercooled water having a much higher free energy than ice at the same temperature and, consequently, a higher vapor pressure. The water droplets evaporate rapidly and condense on the ice crystals. Also, the nucleating process is aided to a significant degree by disturbing the relative positions of the water droplets, an event which obviously occurs when these droplets collide abruptly with the surface of the aircraft. The result of all this is that the aircraft surface becomes wet with a thin layer of supercooled water which quickly crystallizes, turns to ice, and builds up with menacing rapidity.

Droplet Size

Another factor, droplet size, makes a direct contribution to aircraft icing. If the droplets are very small in diameter, they often do not possess sufficient inertia to impinge on the aircraft surface. Many of them tend to follow the air current around the structure. Hence, the degree and rapidity of ice build up depends, to a large extent, on the diameter of the water droplets.

Icing Facility Integrated With Existing Test Installation

After sufficient background information on the characteristics of an icing atmosphere was obtained, the next step was to select the test site. This involved appraising all existing Allison testing installations to determine the most functional and economical location for the icing test system.

The test site selected had to provide the following requirements:

- Control of the air entering the engine with respect to flow rate, temperature, pressure, and humidity
- Control and measurement of the liquid water content of the entering air
- Control of the median droplet diameter of the water entering the engine and provision of measurement instrumentation
- Sufficient room to allow for attachment of the Electra engine air-inlet duct to the engine for the test
- Adaptability of the existing test facility to allow the icing test to be moved in and out readily without

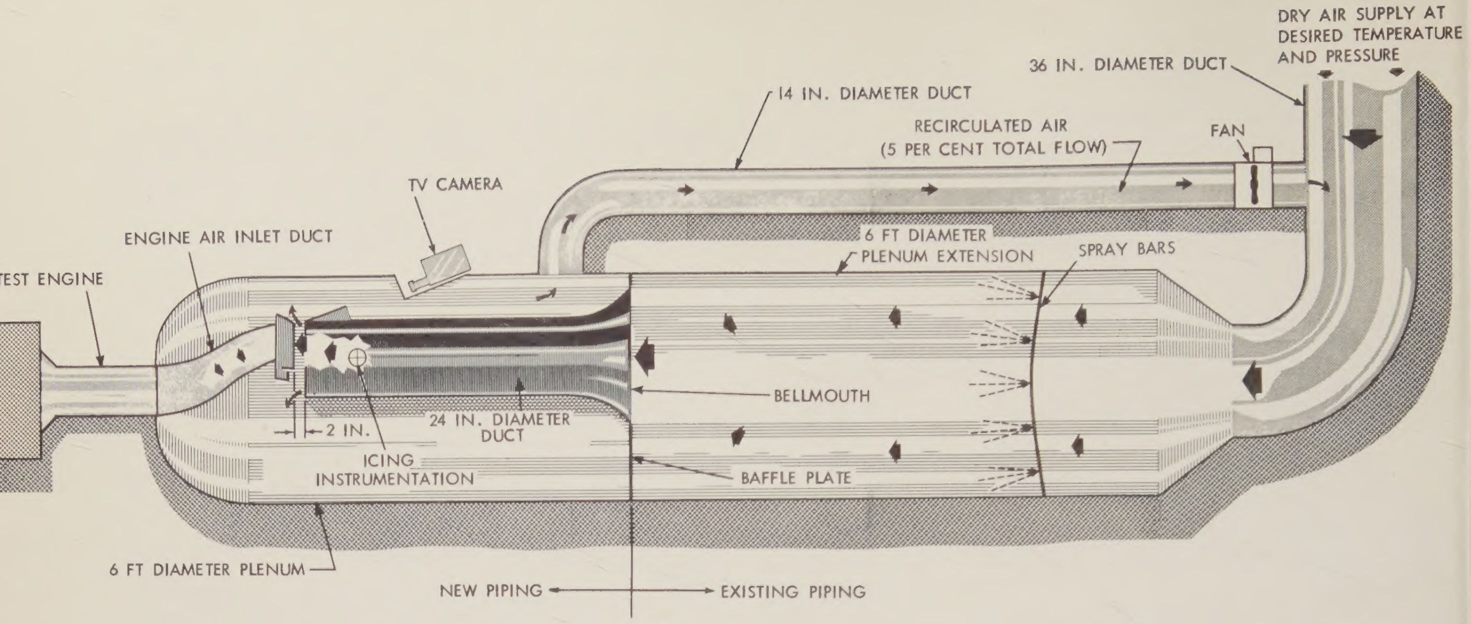

Fig. 2—Illustrated here is the final design configuration of the Allison icing facility for testing the effectiveness of engine anti-icing systems. Metered air enters the test laboratory through a 36-in. diameter duct from the basic air supply facilities. The air is dry and its temperature and pressure are controlled to simulate a particular atmospheric condition. This air passes into a 6-ft diameter plenum where, at a relatively low velocity (approximately 17 fps), the *cloud* is produced by spraying minute droplets of water into the air stream. The cloud then moves through a bellmouth into a 24-in. diameter duct where its velocity is accelerated to approximately 150 fps. The air then enters the engine air inlet duct, passes into the compressor section of the test engine, and is exhausted to the atmosphere through additional laboratory piping (not shown). Instrumentation for determining liquid water content and median droplet diameter is inserted into the air stream 30 in. upstream of the engine air inlet duct. Conditions at the engine inlet are monitored via a closed-circuit television system.

When flying through an icing cloud, the outside surface of the engine air inlet duct lips also is subject to icing. An estimated 5 per cent of the air fed into the icing facility is drawn over this surface. This air is then recirculated back into the 36-in. air supply piping through a 14-in. duct by a vane-axial fan. By the time this air has returned to the laboratory air inlet piping, the supercooled water has frozen out on the surfaces it has contacted, and the air is sufficiently dry for re-use.

disrupting unreasonably the regular schedule of tests assigned to that facility.

The test site selected was the smaller of two existing gas turbine engine compressor test laboratories. This laboratory, serviced by adjacent basic air supply and evacuation facilities, provided ample process air supplied at a wide range of temperatures and pressures. The configuration of the laboratory allowed the icing test system to be designed to fit the existing equipment with little or no compromise. Also, the large amount of permanently installed instrumentation (including automatic data logging equipment) in this laboratory was another complementing feature.

Since ice build up takes place only in the air inlet portion (the compressor section) of a gas turbine engine, the only component of the Electra engine that was set up in the icing test facility was the compressor section. Power to operate the compressor section was supplied by several Allison gas turbine engines driving through gear boxes. This differed from the actual aircraft installation. However, as long as the test component was driven at the proper speed and sufficient power was available, the actual aircraft inlet conditions could be simulated.

Engineering Experience of Others Helped Allison Engineers

With the test location chosen, the actual design and procurement of equipment for the icing test system then proceeded.

Design data and assistance were obtained from several sources. Icing studies in the aviation field have been carried on for a number of years by private industry and by the U. S. Government. Seeking to benefit from the experience of others, Allison test facilities design engineers turned to the Aeronautical Icing Research Laboratory (AIRL), Mt. Washington, New Hampshire, and the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics, now the National Aeronautics and Space Administration (NASA), Cleveland, Ohio, for counsel. AIRL utilizes natural and artificial outdoor atmospheric icing conditions to test engines. NASA conducts its tests on aircraft components in an indoor icing simulation tunnel.

In addition to furnishing general advice on the arrangement of the Allison icing test facility, NASA provided a water spray nozzle design which it had used for several years. NASA test engineers also plotted a complete set of performance curves which enabled Allison engineers to design the water spray system to operate within the proper limits. During actual testing, the performance curves provided a means for accurately setting the desired liquid water content and median droplet diameter without depending on trial and error methods. AIRL provided Allison with instrumentation for determining actual liquid water content and median droplet diameter to take care of immediate testing.

Using the background information obtained on icing atmosphere characteristics plus the engineering assistance and counsel from outside sources, design of the icing test system was initiated and a final configuration achieved (Fig. 2).

Spray System Provides Proper Icing Atmosphere

The water spray system for the icing test facility is designed to provide liquid water contents up to 3 grams per cubic meter of air and median droplet diameters from 10 to 50 microns for normal Allison model 501 engine air flows. Since the water atomizing nozzles utilize air to break up the water spray, separate systems are provided for water and air supply (Fig. 3). The water and the air are heated separately to 170°F to prevent premature freezing.

The liquid water content is directly proportional to nozzle water flow (for a given engine air flow). Median droplet diameter is a function of the ratio of nozzle water flow to nozzle air flow—the greater the water flow with respect to air flow, the larger the median droplet diameter. Since the spray nozzle characteristics are already known, almost any combination of liquid water content and median droplet diameter, within the limits of the system, can be obtained by using the appropriate number of nozzles in conjunction with the proper nozzle water and nozzle air flows.

Although liquid water content *LWC* and median droplet diameter *MDD* can be predicted accurately for the region immediately downstream of the spray bars, a certain amount of water might freeze out as it impinges on the bellmouth and other surfaces before it reaches the engine air inlet. Also, the supercooled drops of water may tend to coalesce. Thus, it is desirable to determine the actual condition at the test engine inlet.

These two factors, *LWC* and *MDD*, are determined from ice build up on a rotating multi-cylinder assembly (Fig. 4). For a short period of time during the test run, this assembly is extended into the icing atmosphere, perpendicular to the engine inlet air stream.

During most of the test run, the rotating multi-cylinder assembly is housed in a closed chamber outside the 6-ft diameter plenum of the test facility. This chamber is kept cold with dry ice and is held at the same static pressure as the test engine inlet.

Trial Icing Run Precedes Actual Test Run

The objective of a particular series of tests is to determine the effectiveness of an engine's anti-icing system under various atmospheric icing conditions. Five factors at the engine air inlet determine every test *set point:* air flow, air temperature, air pressure, liquid water content,

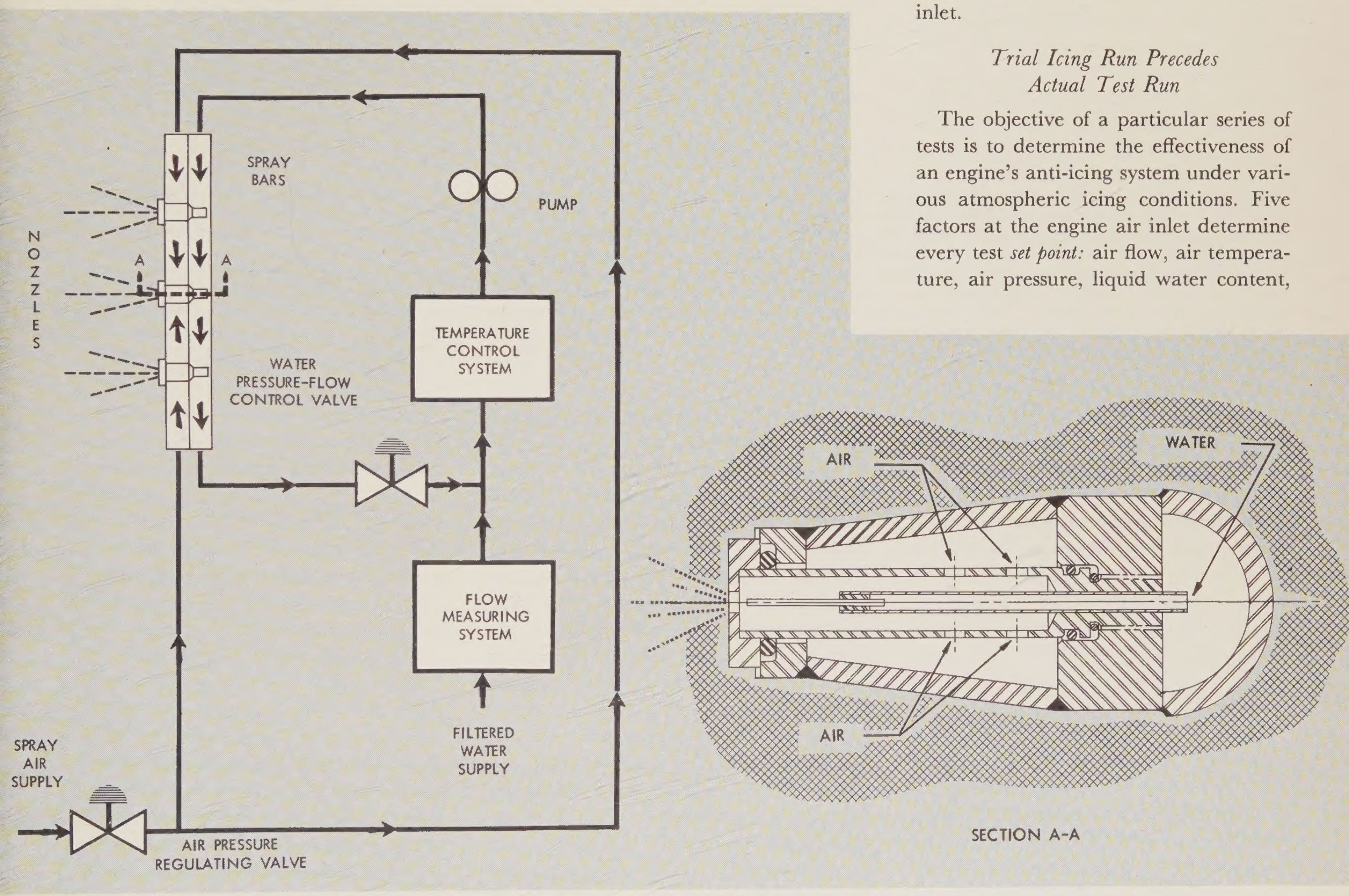

Fig. 3—The water supply system (left) for the icing test facility is comprised of two separate systems—one for water, one for air. Air is used to break up the water spray droplets leaving the water atomizing nozzles.

Filtered water enters the system through a flow measuring device at about 20 psig and passes through a temperature control system to a pump. Since the pump is of the positive displacement type, the flow rate is essentially a constant 5 gpm regardless of output pressure (which, in this case, can be varied between 0 to 130 psig). From the pump, water is sent to five spray bars, which are plumbed in parallel. A small quantity of water is forced out through the nozzles. The remainder of the water passes through the spray bars and the water pressure-flow control valve and then back into the water system upstream of the temperature controller. As the pressure-flow control valve is closed down, the pressure in the spray bars is increased and the water flow through the nozzles into the engine air stream is increased.

Air enters the spray system through a pressure regulating valve and is piped into the spray bars from both ends and out into the engine air stream. There is no recirculation of air, as in the water system; all air is expelled through the nozzles.

Shown at the right is an enlarged view of Section A-A indicating the inner spray bar and nozzle construction.

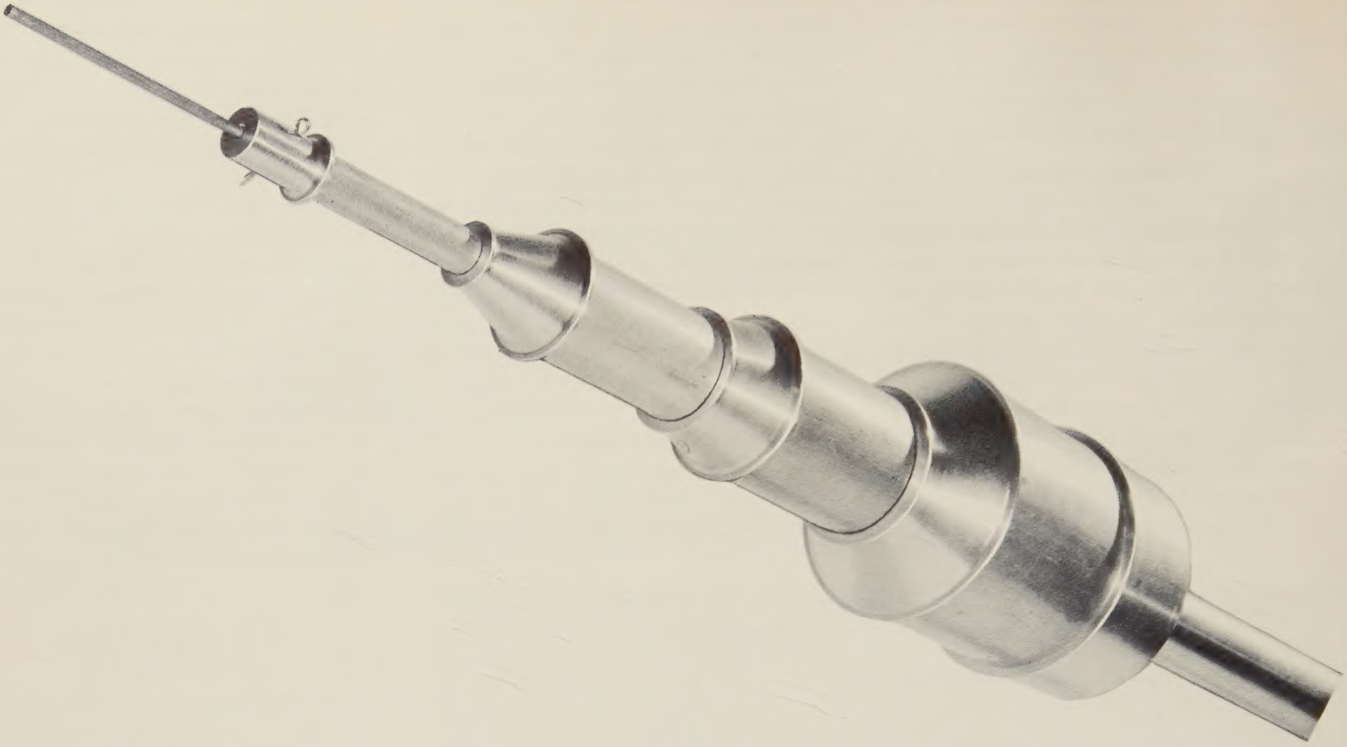

Fig. 4—The actual conditions of liquid water content and median droplet diameter at the engine inlet are determined from the amount of ice collected by the rotating multi-cylinder assembly shown here. Several cylinders of various diameters must be used for proper determination of water content and droplet diameter. The assembly is extended into the icing atmosphere, perpendicular to the inlet air stream. The cylinders are rotated to provide an even film of ice. For best test results, a film of ice having a thickness of between 1/32 in. and 1/16 in. on the smallest cylinder is desirable. Before the assembly is inserted into the air stream it is pre-cooled. Rotation of the cylinders is then started and the assembly quickly inserted into the air stream for the exposure period. Experience aids in estimating the proper exposure time. At the end of exposure, the assembly is quickly retracted into its chamber and the exposure time is recorded. Removal of the assembly from the air stream requires considerable skill. The entire assembly is coated with ice upon removal and the individual cylinders must be separated without losing or melting any of the ice. After removal, each cylinder is placed on its own preweighed container. Once the cylinder is in its container, the ice may melt without affecting the test data, since the *weight* of liquid on the cylinder is the basic concern.

and median droplet diameter. The liquid water content and the median droplet diameter are commonly stated in metric-measurement system terms.

In the Allison spray system a single spray nozzle flows between 7 and 41 lb of water per hour and produces droplets with a median diameter between 10 and 50 microns. Thus, for example, 10 nozzles spray between 70 and 410 lb of water per hour with median droplet diameters between 10 and 50 microns.

The project engineer who assigns the icing tests determines the number of spray nozzles required for a series of set points. To simulate atmospheric icing conditions properly, the nozzles are then arranged in the spray bars in a pattern that produces even distribution of the supercooled water droplets at the engine air inlet. A total of 50 holes is available in the five spray bars for the placement of nozzles. Initial nozzle placement is determined on the basis of experience; the final nozzle arrangement is arrived at by trial icing runs.

A trial icing run is essentially the same as an actual test run except that a grid of 1/8-in. diameter rods on 4-in. centers is placed between the end of a 24-in. diameter duct and the engine air inlet duct (Fig. 2). The ice build up is observed through windows in the side of the 6-ft diameter plenum. After an even icing build up pattern is established on the grid by rearranging nozzles, the grid is removed and everything is in order for an actual test run.

After all factors of flow and pressure, with respect to nozzle spray water and air, are determined, the icing test facility is ready to make a *wet run.* As soon as the compressor section is brought up to speed, operators of the basic air supply facilities set the proper engine inlet air temperature and pressure. A certain amount of soaking time is required to bring all components down to the set point temperature. During these preliminaries, heated air flows at full capacity through the spray bars to keep them well above freezing temperatures. When stabilization of the test engine inlet air flow, temperature, and pressure has been achieved, actual icing may commence.

Actual Test Run Illustrated

To illustrate the sequence of events which take place during an actual test run, assume that the facility is to test the effectiveness of the anti-icing system on the Allison model 501 engine.

The facility is to produce icing conditions at 10,000-ft altitude (20.50 in. of mercury absolute pressure) and 14°F with 2.2-grams per cubic meter liquid water content and a 20-micron median droplet diameter. It is known that the model 501 engine consumes a constant 13.15 cubic meters of air per second. From this, it is calculated that a water flow rate of 230 lb per hour will be necessary to produce the desired liquid water content of 2.2 grams per cubic meter.

The nozzle characteristic curves then are used to determine that a nozzle air flow of 375 lb per hour is required to achieve a 20-micron median droplet diameter. With 10 nozzles installed, this flow occurs at an air pressure of 36 psig.

To produce the artificial cloud, nozzle air pressure is reduced to the desired value of 36 psig. The water pump is then turned on and a water pressure-flow control valve adjusted to produce a 230-lb per hour nozzle water flow.

Conditions in the test engine inlet are observed by a closed circuit television monitor. The camera is placed outside the 6-ft diameter plenum and "looks through" a triple-thickness tempered glass window in the plenum and a plexiglass window in the 24-in. diameter duct. Lights are located inside the 6-ft plenum. At high liquid water contents, the artificial cloud is dense, and it is impossible to see the engine inlet structure. Interrupting the spray water flow for a short period of time causes the cloud to clear and allows observation of the engine inlet condition. The cloud re-forms with resumption of water flow.

Shortly before the end of the test run, an icing sample is taken with the rotating multi-cylinder assembly.

After the sample is taken the spray system is shut down by first shutting off the water pump. The nozzle air flow is then increased to a maximum to purge the spray bars and nozzles of all water and to prevent freezing.

After the spray system is shut down the test engine is stopped. A small quantity of facility air is kept passing through the test engine, however, to preserve temporarily ice that may have built up in the aircraft duct or engine inlet. Photographs are taken and any accumulated ice is allowed to melt. While photographs are being taken, the rotating multi-cylinder assembly is removed.

Test Data Used to Calculate Water Content and Droplet Diameter

To check the liquid water content and median droplet diameter, data collected by the rotating multi-cylinder are analyzed.

A cylinder placed in an air stream perpendicular to flow direction will intercept a column of air, the volume of which is the product of cylinder length and diameter, air stream velocity, and time. This product is termed swept volume V_s. If the column of air contains supercooled water droplets, and if the cylinder diameter is small and the droplet diameter is large, all of the water which enters the swept volume will strike the cylinder and freeze on it. Since conditions are seldom ideal, some of the supercooled water droplets will follow the air stream and not impinge upon the cylinder. The only quantity that can be measured by inserting a cylinder perpendicular to the air stream is the weight of ice collected W_c from the swept volume. The ratio of W_c to the actual weight of supercooled water suspended W_s in the swept volume of air is known as the collection efficiency E.

The collection efficiency, which has been determined empirically, varies directly with droplet size and air stream velocity and inversely with cylinder diameter. Therefore,

$$W_s = \frac{W_c}{E}.$$

Once the actual weight of the supercooled water W_s is calculated, the liquid water content LWC of air entering the engine air inlet duct can be calculated as follows:

$$LWC = \frac{W_s}{V_s}.$$

For proper determination of liquid water content and median droplet diameter, it is necessary to expose several cylinders of different diameters simultaneously to the air stream. Most of the large droplets within the swept volume will be deposited on the cylinders, regardless of cylinder diameter. The smaller droplets, however, will tend to follow the air stream as it passes over and under the cylinders, and the smaller cylinders will collect a greater percentage of small droplets than will the larger cylinders.

The weight of ice deposited on each cylinder is determined by subtracting the dry weight of the cylinder and its container from the weight of the exposed cylinder and its container.

The actual liquid water content and median droplet diameter are determined by plotting certain parameters of ice accretion, duct velocity, temperature, and pressure. The plots then are matched with standard curves developed by Langmuir and Blodgett in their extensive icing research.

Summary

Data from the icing tests run on the Electra model 501-D13 engine and the engine air inlet ducting helped prove to the satisfaction of all concerned that the anti-icing system was entirely adequate. Further confirmation of the effectiveness of the Electra engine's anti-icing system was obtained by actual flights, wherein icing atmospheres all over the continent were sought out and flown through.

At the present time anti-icing system development tests are being conducted on other gas turbine engine models. Design and construction methods employed on the icing-test unit give it a portable nature without compromising its overall efficiency. The unit is readily installed in or removed from the compressor test laboratory, resulting in a minimum of downtime. As on all developmental test equipment, this unit will benefit from continuing design refinements.

The design, installation, and operation of the icing test facility is a typical example of Allison cooperative effort. Basic design parameters were drawn from several outside sources in addition to the Allison engine design, test facilities design, test control, and test operations organizations. In the final analysis, all of the information compiled in achieving this testing installation and in running the tests has been added to Allison's storehouse of test facilities design experience and knowledge.

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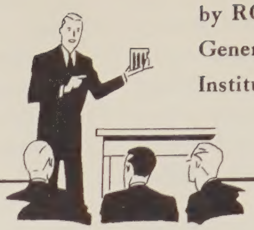
Characteristics and Organization of the Oral Technical Report



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The oral technical report is becoming more popular as a means of communicating information within industry on a variety of subjects. It differs from a written report since it is usually presented in a more personal setting and to a special audience. Because it lacks the scope and permanence of a written report, its effectiveness depends to a large extent on the delivery qualities of the speaker. The oral technical report also differs from other speeches since its purpose is limited to reporting objectively on highly specialized subject matter. However, one characteristic it shares with all means of communication is that to be effective it must be presented on a level the audience is able to comprehend. Proper organization is vital for an oral technical report. A checklist has been devised by General Motors Institute that summarizes the important points to remember in preparing and presenting the oral report.

Visual aids, question period can be utilized to improve the report

THE use of the oral technical report is increasing as a means of communicating information within industry. An engineer may be called on to investigate and report on such things as a production problem, a new manufacturing method, a new material, new equipment, or a new layout. He may make only an oral report on his findings, or he may present the oral report along with a written report. It may be a progress report or a final report and it may or may not contain recommendations.

But what is an oral technical report? How does it differ from a written technical report? How does it differ from a speech for any other occasion?

The oral technical report has characteristics which distinguish it from other forms of communication. There is, however, one essential feature it shares with all forms of communication—namely, to be effective the communication must "get through" to the listener or reader. Any communication must be prepared with the thought as to what background must be provided, what terms must be defined, and how the thoughts should be arranged. If the reader or listener cannot follow a communication with at least a reasonable degree of understanding, it makes little difference how thorough the investigation, how clear the language, or how polished the presentation—the report is a failure. This is as true as if it were a product designed for the market. No matter how ingenious, well made, or attractive it might be, if it does not sell, it has failed to fulfill its purpose.

Oral Report Differs From Written Report

It is easy to form misconceptions when comparing the oral report to the written report and to believe that the oral report consists merely of the written report read aloud, that it is a "boiled down" version of the written report, or that the oral report is somehow better than the written report, or vice versa. The fact is that the two are not identical, nor is either better than the other. Each is prepared for a different situation and each has its advantages and disadvantages.

Four basic characteristics of the oral report distinguish it from the written report.

Special Audience

The written report, once in print, may be read by any number of individuals. The writer, therefore, must try to adapt his writing to a broad level of reader understanding and interests. The oral report, however, is usually prepared for a special audience—for example, a project committee, a safety committee, a design staff—and the speaker must prepare his report specifically to the particular interests and level of understanding of this audience.

Limited Scope

The reader of a written report may read the entire report or only certain parts. The amount of material included in a written report, therefore, may be comparatively unlimited but should include, of course, all pertinent data, either in the body of the report or in an appendix.

The oral report, however, is usually prepared with a specified time limit in mind and the speaker must adapt the scope of his material to fit the time limit, which may include a question and answer period.

Keeping in mind a definite time limit, the speaker must prepare his report to include a clear explanation of the problem and the main sub-conclusions and general conclusions reached. Most of the detailed substantiating data may be omitted, with perhaps a brief description of the general methods used to arrive at the conclusions being retained. If the speaker has also prepared a written report on the same subject, he may limit his talk to only one or two phases covered by the report. As a guiding principle, it is better to cover less, but cover it thoroughly, than to try to cover too much and do only a superficial job.

Personal Presentation

The medium of the written report is the printed page, but the medium of the oral report is the speaker (Fig. 1). Therefore, the delivery of the speaker becomes of critical importance. His posture, gestures, eye contact, and facial expression, as well as his general appearance, are bound to affect the attitude of the audience. So are such factors as his voice projection, enunciation, pronunciation, and the degree to which his speaking style seems relaxed, conversational, and expressive.

A question may arise as to what method of preparation gives the most effective style of delivery. Of the four methods available—impromptu, extemporaneous, manuscript, or memorized—the extemporaneous is usually preferred. In this method the outline of the speech is carefully prepared, but the speech is neither written nor committed to memory. The impromptu method is obviously inappropriate, while the manuscript and memorized methods tend to be inflexible and sound artificial.

Another implication arising from the oral presentation concerns the language. In the written report the language is properly impersonal and formal. Only in the letter of transmittal does the writer use such personal pronouns as "I" or "you" and at no time does he use colloquialisms or slang. But since the oral report is delivered in a setting more informal and personal, the language may also be more informal and personal. The speaker may say "I" or "he" or "they didn't" freely, and even such colloquialisms as "we had a terrible time getting the thing to work," provided he maintains an attitude that is essentially objective and businesslike, and is careful to be specific and accurate where he needs to be.

The opportunity for questions from the audience is another characteristic of the oral report. Sometimes, the questions may be asked as they arise during the presentation, or they may be deferred to a question and answer period following the formal presentation. While each method has its advantages, it is usually more satisfactory to defer any extensive questioning until the formal presentation has been completed.

An appropriate physical setting for the oral report also is important. The location normally is in a conference room comfortable in size for the number attending. Ideally, it should be equipped with a lectern, chart stand, and blackboard, and should be capable of being darkened for possible screen projections. The room should be reasonably free from noise distractions. The general atmosphere, as in the conference situation, is informal.

Instant Understanding

If some portion of a written report is not immediately clear, the reader may reread it, refer back or ahead, or even consult other sources. But the oral report disappears into thin air the moment it is presented. This means that the speaker must be exceedingly careful to be as clear as possible.

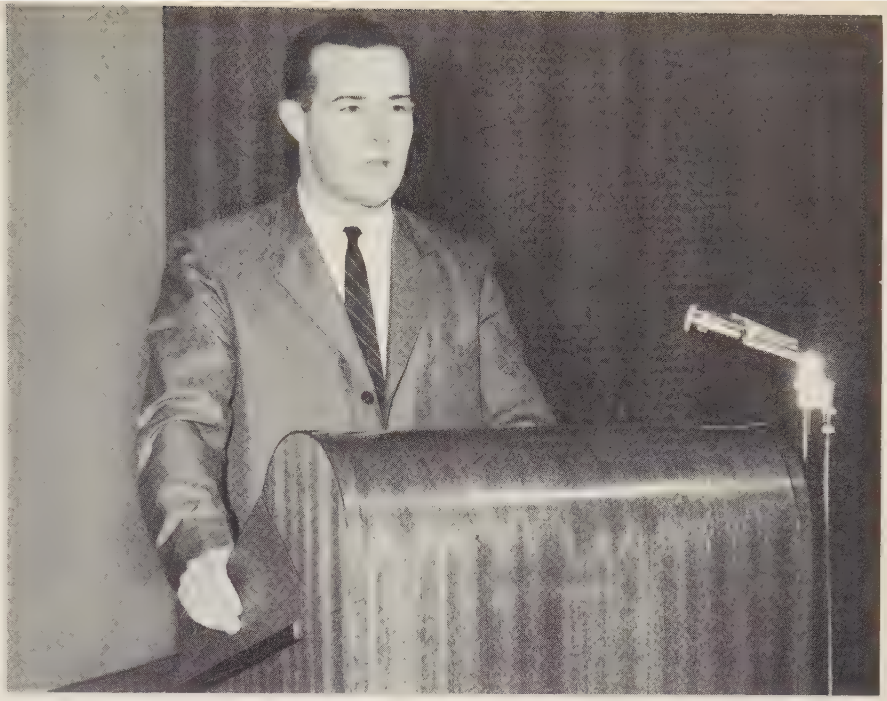


Fig. 1—The success of an oral technical report depends to a large degree on its delivery by the speaker. An example of correct posture, eye contact, and neat appearance necessary for an effective oral report is shown here by a General Motors Institute fifth-year student delivering his report to management.

Three ways to facilitate instant understanding are:

(a) *Use of Voice:* the speaker can help the listener if he uses his voice properly. First, he must project adequately and enunciate distinctly so that even those seated farthest away will have no difficulty hearing him. Second, he should use pauses freely to break up his flow of ideas into meaningful thought units and give an opportunity for his ideas to "soak in." Finally, he should speak with sufficient forcefulness and use a variety of voice inflection, not only to avoid monotony, but also to give life and meaning to his words

(b) *Use of Language:* the speaker can help his listeners by using language that is easy to understand. If the reader of a written report encounters an unfamiliar term he can refer to a dictionary. But in an oral report, the speaker must define the term for the listener. Obviously, the problem will vary from one situation to another, but the speaker should be sure the listeners understand his terminology since he may be using special terms or else familiar terms with special meanings. This problem of terminology can be a major one in writing as well as in speaking. Different branches of engineering have become so specialized in their jargon that engineers in different departments often have difficulty in understanding each other. Not only must the terminology be clear, but the language must not be too abstract or involved

(c) *Use of Transitions and Summaries:* the third way for easier listener comprehension is in the use of transitions and summaries. It is not enough that the speaker understand his pattern of development. He also must make it constantly clear to his listeners. Having developed a section of his report, he should summarize it briefly before moving to the next section and should show the relationship between the various sections. The main preview of his report will occur, of course, in the introduction, and the main summary in the conclusion.

Instant understanding is absolutely vital in the oral report. It is difficult to emphasize enough the importance of the speaker being constantly solicitous of the listener's need to "keep with" the report as it is presented.

Basically, the oral technical report is a different medium of communication

EVALUATION OF THE ORAL REPORT

	YES	NO	
Introduction			Did the speaker effectively capture the interest and attention of his review group right from the start?
			Did the speaker give the necessary explanation of the background from which the problem derived?
			Did the speaker clearly state and explain his problem?
			Did the speaker indicate the method(s) used to solve the problem?
			Did the speaker suggest the order in which he would report?
Organization			Was the plan of organization recognizable through the use of:
			(a) Sufficient introductory information
			(b) Successful use of transitions from one main part to the next and between points of the speech
			(c) Appropriate use of summary statements and restatements?
			Were the main ideas of the report clearly distinguishable from one another?
			Was there a recognizable progression of ideas that naturally led to the conclusion?
Content			Did the speaker have adequate supporting data to substantiate what he said?
			Was all the content meaningful in terms of the problem and its solution? (Avoidance of extraneous material.)
			Did the speaker present his supporting data understandably in terms of the ideas or concepts he was trying to communicate?
			Were the methods of the investigation clearly presented?
Visual Aid Supports			Did the speaker effectively use charts, graphs, or diagrams to present his statistical data?
			Did the speaker use clear drawings, charts, diagrams or blackboard aids to make his facts or explanations vivid to the review group?
			Did the visual aids fit naturally into the presentation?
			Did the speaker give evidence of complete familiarity with each visual aid used?
			Did the speaker clutter his report with too many visual aids?
Conclusion			Did the speaker conclude his report with finality in terms of one or more of the following:
			(a) The conclusions reached
			(b) The problem solved
			(c) The results obtained
			(d) The value of such findings to the corporation or industry at large
			(e) Recommendations offered?
The Question Period			Did the speaker give evidence of intelligent listening in interpreting the questions?
			Were the speaker's answers organized in terms of a summary statement, explanation, and supporting example?
			Did the speaker show freedom in adapting or improvising visual aids in answering questions?
Delivery			Did the speaker use a natural, communicative delivery?
			Did the speaker use adequate eye contact in maintaining a natural, communicative delivery?
			Did the speaker use sufficient movement and gestures?
			Did the speaker use good clear diction to express himself?
			Could the speaker be heard easily by everyone?
			Was the speaker confident and convincing?
			Did the speaker display enthusiasm when communicating his ideas?

Table I—This checklist for the evaluation of an oral technical report was developed at General Motors Institute. It gives a concise view of the qualities demanded in the oral report.

from the written technical report and is designed for a different kind of communication situation. It also differs from non-technical speaking.

Main Purpose of Oral Technical Report: to Inform

A speaker may attempt to secure any one of three basic responses from his audience. He may want them to be entertained or interested (as in the case of the after-dinner speaker); to believe or act differently (as in the case of a safety talk); or to understand (as in the case of directions on how to operate a machine). Basically, the oral technical report is expository or informational. The speaker should strive for all three basic responses, but his main purpose is to advance the audience's understanding of the topic under discussion.

If the main purpose of the oral technical report is to inform, the speaker must be objective and impartial towards his material. Even though he may present strong advantages in favor of some recommendation, he scrupulously presents its disadvantages as well. The speaker stops short of playing the role of the advocate arguing for the adoption of a special point of view. He is more like a scientist reporting his latest findings to a group of fellow scientists.

In keeping with the objective point of view, the development of the oral technical report is primarily factual. Although an occasional anecdote may be valuable for illustration or enlivenment, the body of the report should consist of such objective data as explanations, descriptions, definition, statistics, and expert opinion. Any conclusions offered should be based strictly on the facts available.

Yet, the speaker must take care that emphasis on the data does not obscure understanding of what the data support. An example of this is the speaker who is so preoccupied with explaining certain equations employed in his study that he never makes clear what his equations were intended to prove, nor what results they produced.

Although an oral technical report does not necessarily need the use of visual aids, they are usually recommended. Graphs, diagrams, models, and samples are employed freely for such purposes as explaining mechanisms and processes, presenting statistics, and stating objectives or listing main points. Because it is so easy to use visual aids ineptly, a few suggestions are:

- Charts and diagrams should normally be prepared before instead of during the presentation, when valuable time may be needlessly consumed
- Aids should be kept simple, focusing only on what is most pertinent
- Each drawing or chart should be adequately titled and labeled
- Diagrams and labels should be large enough to be fully legible to those seated farthest away
- Charts should have a professional look. Drawings and lettering not neat in appearance detract from the report
- Normally, materials should not be distributed during the presentation since they divert attention from the speaker
- Aids should not be revealed until they become pertinent in the presentation.

Proper Organization Important for Effective Report

As in any form of communication, the pattern of development is very important. The organization of the oral technical report can be most conveniently discussed in terms of the three major divisions of the report: body, introduction, and conclusion.

The *body* is normally organized in terms of the steps involved in the problem-solution sequence. They include:

(a) An analysis of the problem to show what is wrong (the evidences of effects of the problem); the conditions which brought about the problem (the causes); and a statement of what is desired (the criteria or expectations)

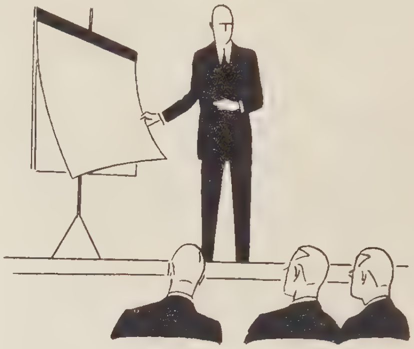
(b) An explanation and analysis of one or more solutions in terms of their advantages and disadvantages in solving the problem and meeting the criteria.

The report need not always follow the entire sequence. Sometimes it may only analyze the causes of a problem or explain and evaluate a solution to a problem.

The discussion of each phase of the analysis should close with a statement showing the sub-conclusions arrived at during that phase.

The *introduction* prepares the audience for the body of the report. This is done by motivating the listener to want to hear what the speaker has to say and orienting the listener as to what the report contains.

Motivating the audience depends on two steps. First, the speaker should dwell briefly on the importance of the problem so the listener will have the feeling, "Here's something I want to find out about." Second, the speaker should establish the distinct impression that he has something worthwhile to offer on this subject. This can be done indirectly by referring to the speaker's interest and background concerning the problem and particularly to the amount of time spent and methods used in his investigation. Another way is to create an impression of competence, both in the introduction and throughout the report.



Orienting the listener is accomplished by:

(a) Identifying and defining the problem by showing its relationship to the area from which it was taken, making clear what phases of the problem will be included in the report, and being explicit as to the exact purpose of the report

(b) Providing whatever background is necessary concerning how the problem arose

(c) Giving a preview of what the main divisions of the report will contain.

When the introduction is completed, the listener should be motivated to want to listen to the report and should know what it will cover and in what order.

The *conclusion* normally fulfills three main functions. First, the various sub-conclusions presented during the report at the close of each unit are summarized. Second, general conclusions, in the form of generalizations drawn from the sub-conclusions, are presented. And finally, any recommendations, arising from the general conclusions are offered. The conclusion normally will provide a transition to the question-and-answer period.

At General Motors Institute, many of the points discussed have been summarized in a checklist to help obtain a uniform evaluation of oral reports presented by students (Table I). These oral reports, in many cases, are required in addition to regular written reports which are a part of the Fifth-Year Program at the Institute. In this fifth year, graduates of the four-year cooperative engineering program are assigned, and must complete satisfactorily, an extensive plant project to qualify for the degree of bachelor of mechanical engineering or bachelor of industrial engineering.

Summary

The oral technical report is becoming more popular as a means of communication. Any engineer may be required at some time to prepare one on a variety of subjects. Although it has many characteristics found in other forms of communication, the oral technical report differs from both the written report and non-technical speech in several aspects. Properly used, it can be a useful tool in industry.

Some Comments on the Importance of Effective Technical Communications

TODAY, written and oral communications are becoming more important as basic tools used by engineers to report the results of an engineering program, explain a new design or development to fellow engineers, sell ideas to management, or inform the general public about scientific and technical developments. Engineering students should understand early in their formal training that written and oral communications are as much an engineering tool as a basic engineering fundamental. Such an understanding will add to their effectiveness as engineers.

Many opportunities are provided an engineer to practice and perfect the art of effective communications. The writing of engineering reports and technical papers and the preparation of speeches for presentation before technical societies, management groups, and educational and civic organizations are typical.

For some reason, engineers too often think their part in an engineering program is over once tests have been completed, drawings made, or a prototype design developed. One of the most important jobs of an engineer, however, is to communicate to management the results of his work. This, of course, is done by means of the engineering report.

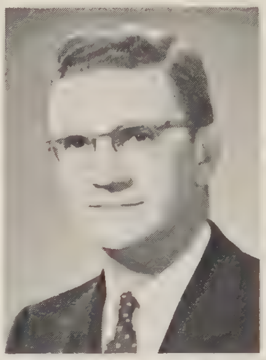
The written report often is the only record made of results representing thought, effort, time, and money. The engineer who writes the report assumes a responsibility. He has been closest to the project. He understands the data the report presents. If he does not write a clear and factual report which can be understood and used by individuals not as familiar with the project as he is, then the report loses much of its value. This is especially true if the report must be referred to three or four years after it was written.

The preparation and writing of accurate and meaningful engineering reports should be approached with the same deliberation and thoroughness used in setting up and carrying out an engineering development program. This is, perhaps, a rather basic fact, but one that is often overlooked.

The engineer writing a technical paper for publication also assumes a responsibility. He is going to share information with his fellow engineers. To be of value to the profession, therefore, the paper must be clearly written so there will be no misunderstanding between the writer and his audience. A good technical paper reflects the quality of the engineer's work. This, in turn, reflects credit on the firm with which he is associated.

The writing of a report or technical paper requires the engineer to clarify his thoughts and arrive at a clear and concise understanding of his subject. Often a man will have an idea in mind but when he tries to communicate that idea to someone else he finds that he has not thought the subject through clearly. A little time spent in preparing a good outline forces him to sharpen his thoughts and makes the writing of the paper easier.

The recent emergence of the engineer as a most important member of society has placed him in a position where he is called on to appear before non-technical groups to speak on matters of science and technology. This provides another opportunity for him to practice the art of effective communications. Delivering a talk on a complex technical or scientific subject before a non-technical audience requires the engineer to keep his audience in mind when preparing the speech. The degree of technical jargon must be adjusted to fit the level of the audience he is to address, or else the effectiveness of the speech is lost.



Preparing a speech, therefore, requires as much thought as writing an engineering report or technical paper. There is one more ingredient required, however, for a speech—rehearsal. Woe be to the engineer who tries to deliver his first speech with no rehearsal. That should be a lesson to hold him for a lifetime.

The engineer who masters the art of effective communications can reap several incidental benefits. He will gain personal satisfaction in knowing he has communicated to others information with which only he was familiar and experienced. He will gain prestige within the profession. He will become known as an individual of sound reasoning ability and a careful observer.

Lastly, I believe that the art of proper communications—especially oral communications—will aid in developing leadership ability. For leaders lead by talking, explaining, and inspiring. They cannot lead by being behind and pushing.

Martin J. Caserio

MARTIN J. CASERIO,
General Manager
Delco Radio Division

GM Division Gives Course in Freehand Sketching

The ability to make a freehand pictorial sketch to communicate ideas quickly and effectively is an important requirement in the work of the engineer. To perfect this ability requires practice to master the various types of freehand sketches used to show an object to its best advantage.

To provide an opportunity for review, practice, and further training in the basic principles of three-dimensional freehand sketching, Saginaw Steering Gear Division recently arranged a Freehand Pictorial Engineering Design Sketching Course for 25 of its product engineers. The course, conducted at Saginaw by Professor Raymond C. Scott, University of Michigan, was given for a period of sixteen, two-hour meetings.

The course work covered a review of the various types of pictorial sketches and their practical application, with emphasis given to proportional relationship of parts. Pictorial representations reviewed included isometric, dimetric, trimetric, oblique, cavalier, and cabinet drawing. Also reviewed were sectional, assembly, and exploded views, and shading techniques.

Since the course proved so effective, Saginaw Steering Gear expects to present it again.

A freehand sketching course was recently given by Saginaw Steering Gear Division for product engineers. The course was conducted by Professor Raymond C. Scott, University of Michigan, shown here describing a freehand sketching problem to the class.

The sketching course provided engineers the opportunity to review, practice, and receive further training in the fundamentals of three-dimensional freehand sketching.

Laboratory Testing Verifies Design of Lightweight Fabricated Frame for Highway Tractors

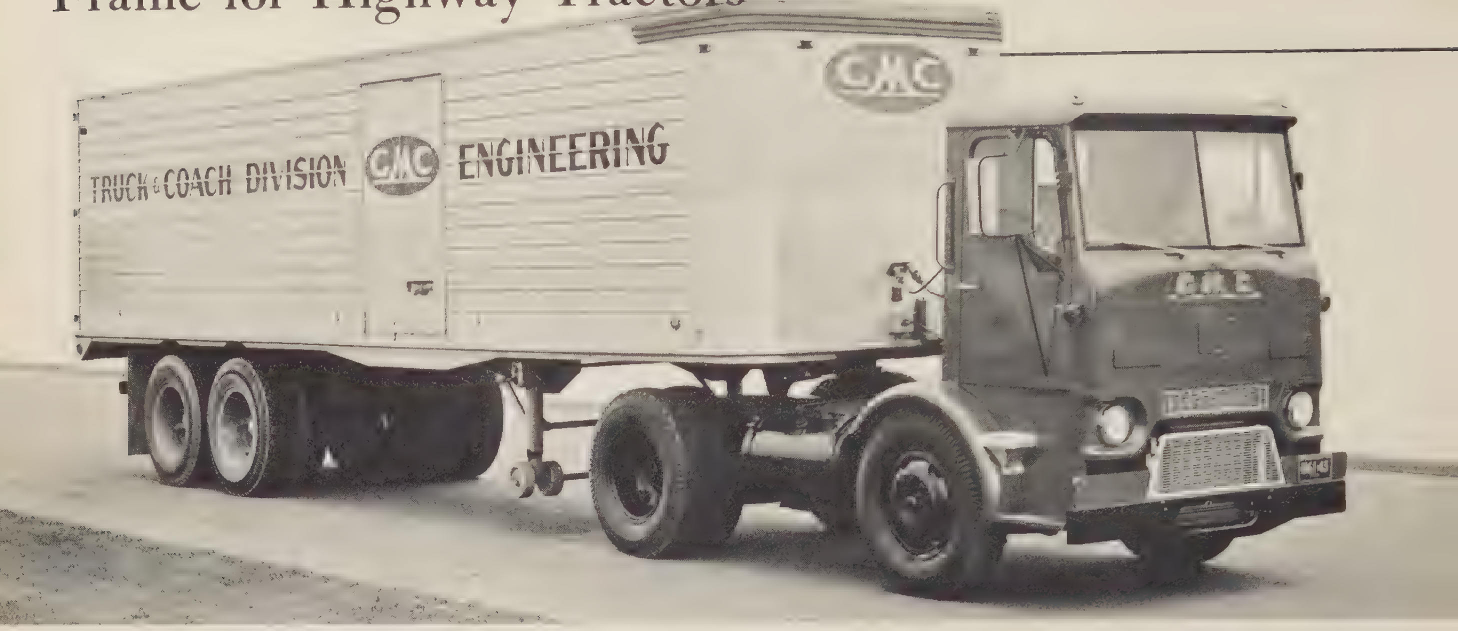


Fig. 1—The new GMC highway tractor model DLR-8000 is rated at 61,000 lb gross combination weight (tractor, trailer, and load) and is available in a 108-in. wheelbase to provide optimum front axle loading with either standard or sleeper cab. By keeping overall weight of tractor at a minimum, over 1,800 lb more payload is obtained.

One objective of a long range engineering program originated by the GMC Truck and Coach Division in the fall of 1957 was the development of an extremely lightweight Diesel-powered highway tractor with short cab dimensions. This tractor was to utilize materials to their best advantage to keep overall weight as low as possible without sacrifice of design strength. One component which contributed to weight saving was the frame. In place of the usual channel type frame, a new type of frame was designed, based on a very deep welded I-beam type construction using $\frac{3}{16}$ in. top flanges continuously welded to light steel webs. SAE 950 steel was selected for the frame material since it provided high strength and good weldability without high cost. Laboratory tests conducted on the frame highlighted critical stress areas and proved the merits of redesign in these areas. The brittle lacquer and strain gage techniques were applied to locate and measure accurately the unit deformation of the frame.

In the fall of 1957 the GMC Truck and Coach Division initiated a long range engineering development program. The objective was the development of new truck engineering concepts, based on a re-evaluation of truck design principles, which would provide truck operators with economic benefits through decreased operating costs and greater ease and efficiency in transporting loads.

Included in the specific goals of the development program were:

- Development of lightweight, heavy duty highway tractors
- Development of new engines having improved performance characteristics, longer life, and more economy, yet compact enough to fit into shorter length cabs
- Development of improved suspension, steering, and power transmission systems
- Simplification in design of component parts for all truck models to provide more interchangeability of parts.

During 1958 the more immediate effects of the engineering development program were felt with the introduction of the GMC model DR862 and DR860 heavy duty highway tractors. These tractors had air suspension and used one of its benefits—elimination of most high frequency road vibrations and shocks before they reached the chassis and cab—to reduce structural strength requirements and permit a liberal use of aluminum in place of steel for the cab. The tractors had a 90-in. bumper-to-back-of-cab measurement and weighed half a ton less than previous models of the same GCW rating (gross combination weight rating comprised of tractor, trailer, and load).

In the spring of 1959 the first major results of the long range engineering development program were realized with the introduction of the GMC series 8000 heavy duty highway tractor (Fig. 1). This tractor, measuring 48 in. from bumper to back of cab, was designed specifically to fill a need for a lightweight highway tractor. The 48-in. cab permits hauling maximum payloads in certain states favoring "double bottom" hauling—that is, highway tractors hauling a semi-trailer plus a full trailer.

Included in the engineering features of the series 8000 tractor are: independent front wheel suspension with air springs, riveted aluminum cab construction, air springs to carry the rear axle load, and fabricated frame of I-beam type construction in place of the usual channel type frame (Fig. 2).

The use of air springs gives the tractor

By JOHN G. LOCKLIN
and FRANCIS C. FLECK
GMC Truck and
Coach Division

The truck frame that talked back to the engineer

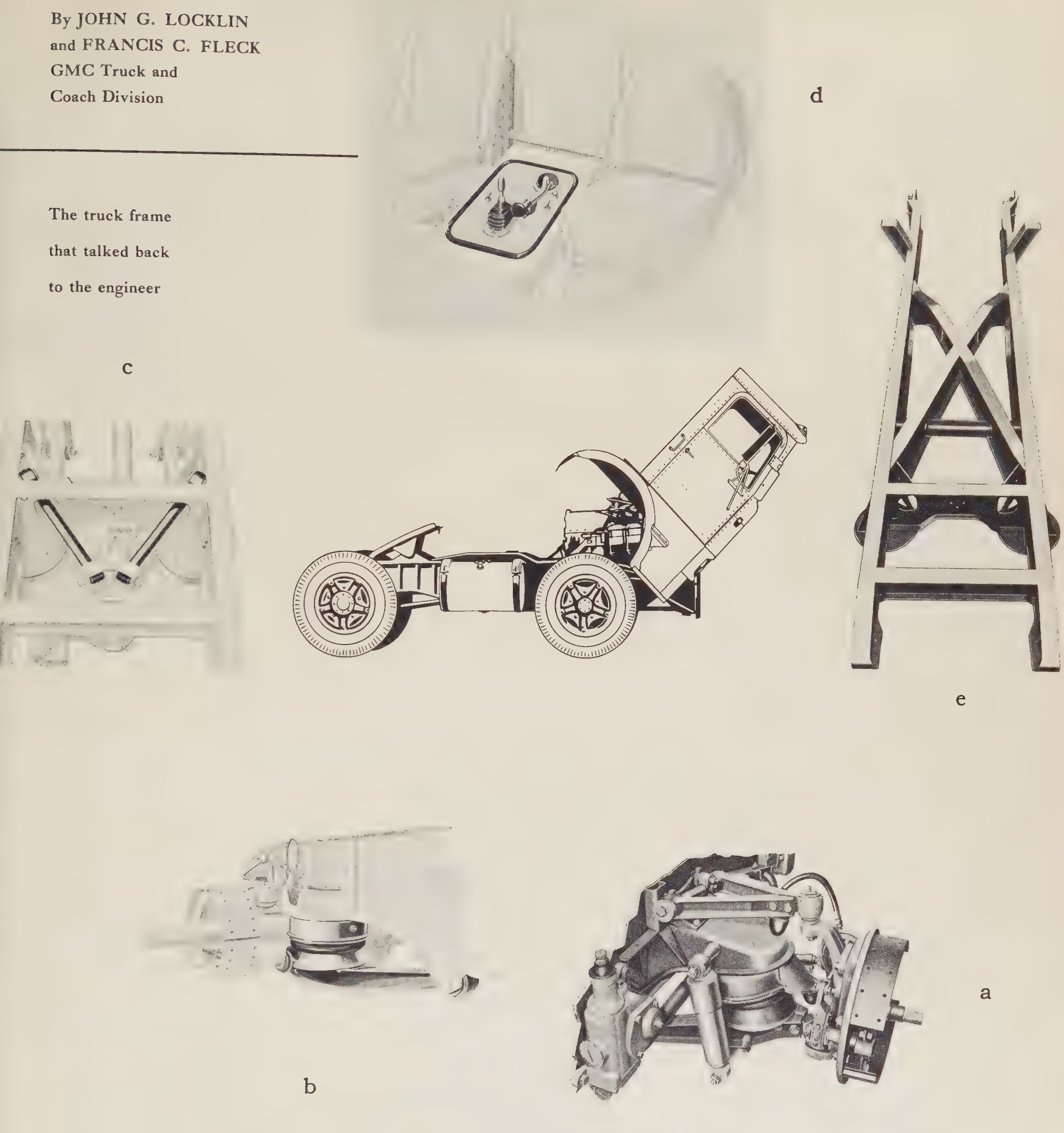
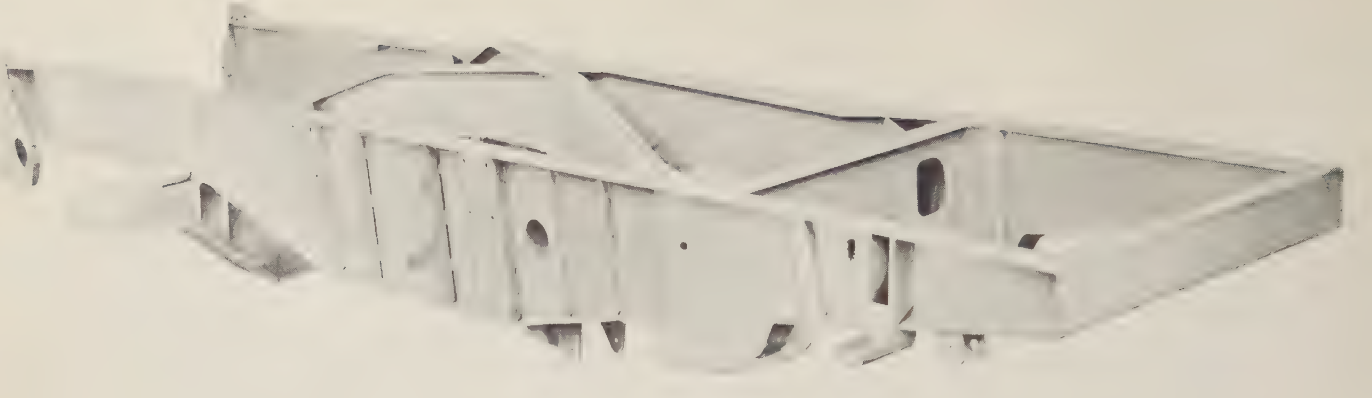


Fig. 2—Included in the engineering features of the GMC series 8000 lightweight, heavy duty tractor is a riveted aluminum tilt-cab, which measures 48 in. from bumper to back of cab. The cab can be tilted forward manually because cab weight is counterbalanced by a torsion bar type spring. An independent front wheel suspension (a) eliminates the usual heavy front axle and saves on overall weight. Air suspension systems for both front and rear are designed to use a single convolution type of air diaphragm. The individual cylinders eliminate the need for an additional air reservoir, such as previously provided with a tubular axle. The rear axle air springs fit between the frame and the lower radius arms (b). The two upper and two lower arms provide four-link axle control. The upper links, located over the rear axle (c), eliminate lateral sway and give the air suspension the required stability. The four basic operating controls (gearshift lever, emergency brake, throttle, and engine emergency stop) are located on a "control island" (d), which remains in a fixed position when the cab is tilted. This feature eliminates the need for long, flexible control cables and rods. A new type of welded frame (e), weighing approximately half as much as a conventional channel type frame, uses I-beam sections as the basic building unit.



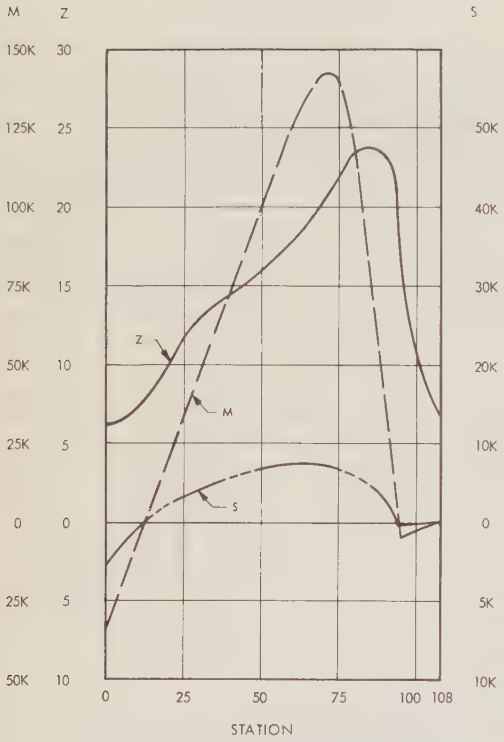


Fig. 3—The welded frame assembly (top) for the series 8000 tractor weighs approximately 400 lb less than a conventional channel frame, yet provides 1.6 times more beaming stiffness and 27.8 times more torsional stiffness. Using a welded construction permitted varying the frame depth to suit the bending moment in order to achieve more uniform stresses. The chart at the bottom shows the comparatively flat stress curve for the frame for static rated load conditions from the 0-in. station at the front axle to the 108-in. station at the rear axle. The letter *K* denotes kips. The *S* scale is tension stress in the lower flange of the frame (lb per sq in.). The *M* scale is imposed bending moment (lb-in.). The *Z* scale is the section modulus per side (in.^{3}).

a constant front and rear height and provides a ride frequency which varies little with load conditions. The elimination of interleaf friction further improves the ride and reduces high frequency vibration transfer to structural parts.

The independent front wheel suspension provides additional resistance to roll, or side sway. The front roll center of the tractor is lowered nearly to ground level, inclining the roll axis and increasing the height of the center of gravity of the tractor above the axis. This increase in height would apparently provide less roll rate if it were not for the fact that the roll rate varies as the square of the effective distance between spring centers. For an independent type of front suspension the span between wheel centerlines is effective, instead of merely the distance between spring centers. With equal ride rates the net roll resisting moment of the independent front suspension is usually about four times that of a conventional I-beam axle suspension. The lower ride rate of the air springs reduces somewhat the roll rate of the suspension, but for the 8000 series tractor it remains about three times the roll rate of a conventional axle with leaf springs.

Lightweight, High Strength Frame Developed

Contributing most to the lightweight features of the series 8000 tractor is the frame. In addition to meeting a requirement of minimum weight, the frame had to meet requirements of high beam strength, bending rigidity, and torsional rigidity. Also of importance was a manufacturing requirement of minimum tooling to fabricate the frame.

To meet these requirements, a design approach somewhat different from that usually applied to highway tractor frames was used.

High Beam Strength and Bending Rigidity

The design approach used to meet requirements of high beam strength and bending rigidity was to increase the depth of the frame rather than the section thickness, as is the practice with conventional channel rails. An I-section was selected as the basic building unit for the frame because its distribution of material was particularly efficient in providing bending rigidity.

Using a welded construction for the frame permitted varying the frame depth to suit the bending moment in order to achieve more uniform stresses. The welded construction also contributed to rigidity, since the flexibility of a welded joint under a load is less than riveted or bolted joints used on conventional channel frames.

Torsional Rigidity

Sufficient torsional rigidity was necessary to make the high roll rate of the front suspension effective at the *fifth wheel**, where forces from a loaded trailer are concentrated to produce lateral loads. The inefficiency of the I-section to resist torsional loads was overcome by designing an X-member into the frame assembly (Fig. 2e). The diagonal members of the X acted as beams to resist twisting of the frame.

Minimum Weight

The welded construction of the frame not only contributed to meeting strength and rigidity requirements but also to meeting the minimum weight requirement. Since the stress for a simple beam is found by dividing the bending moment by the section modulus, which varies as the square of the depth of the section, the weight saving advantages made possible

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*The *fifth wheel*, used to attach a semi-trailer to a highway tractor, consists of a base rigidly mounted to the frame and connected through a pivot joint to a plate assembly. The plate assembly incorporates a latch mechanism used to couple or un-couple the trailer.

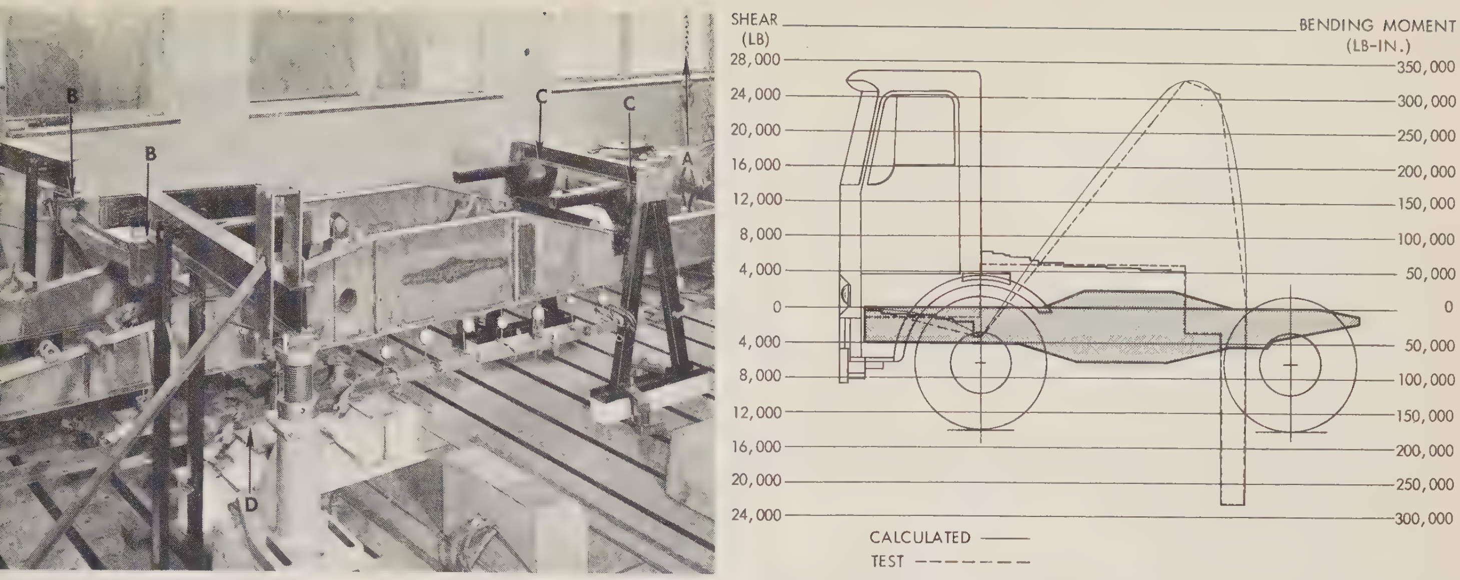


Fig. 4—For the 3g vertical load test it was necessary to simulate as closely as possible the calculated shear and bending moment diagrams for the frame. The test set up is shown in the left illustration. The frame is in the upside down position with the rear of the frame at the left. Loads were applied at point *A* and at the two points marked *B*. The load at point *A* was located 43.8 in. ahead of the front suspension. This load, which simulated loads ahead of the independent front suspension, had a magnitude of 2,850 lb. The load applied at points *B* had a magnitude of 23,282 lb. Points *C* and *D* are reactions. The reaction at points *C*, the front suspension location, was 9,114 lb. The reaction at point *D*, which represented the reaction at the fifth wheel, had a magnitude of 61,941 lb. The deflection of the frame from vertical bending was measured by the indicators shown positioned beneath the frame. The vertical stiffness of the frame at the fifth wheel was found to be 10 times greater than on a frame of comparable wheelbase using the standard channel-type side rails.

The diagram at the right shows the close agreement between the calculated (solid line) and test (dashed line) shear and bending moment curves.

by having the frame depth vary to suit the bending moment become apparent (Fig. 3). Furthermore, since the vertical web of an I-section contributes the least to the section modulus, a thinner web was possible. Thickness was set at 1/16 in. for the vertical web and 3/16 in. for the flange.

The use of high strength, low alloy SAE 950 steel also contributed to meeting the minimum weight requirement, since higher stresses could safely be supported. The minimum yield point of SAE 950 steel for the thicknesses used in the frame is 50,000 psi, compared to a minimum yield point of approximately 31,000 psi for SAE 1023 steel commonly used in channel side members for tractor frames. The higher yield strength of the SAE 950 steel is not depreciated by welding, as would be the case if heat treated steel were used.

Minimum Tooling

The manufacturing requirement of minimum tooling was met by using a combination of relatively simple pieces welded into a complete assembly. A minimum number of specially formed parts (requiring additional tooling charges) resulted.

The principal use of tooling is in the welding fixtures. Inert gas arc welding is used because of the excellent penetration and soundness of welds produced and the higher welding speeds obtained. About 50 per cent of the welding can be done by an automatic welding machine which uses the flange of the I-beam frame as a guide and positions the welding head accurately for a smooth weld of the flange and the web.

The design approach also resulted in other manufacturing advantages. Since the frame assembly can be made of flat pieces, parts for frames do not require special storage areas or special handling equipment. Also, through the interchange of a few center flanges and web pieces, a variety of wheelbase possibilities is provided without requiring large amounts of storage area. A range of several wheelbases is very desirable in this class of

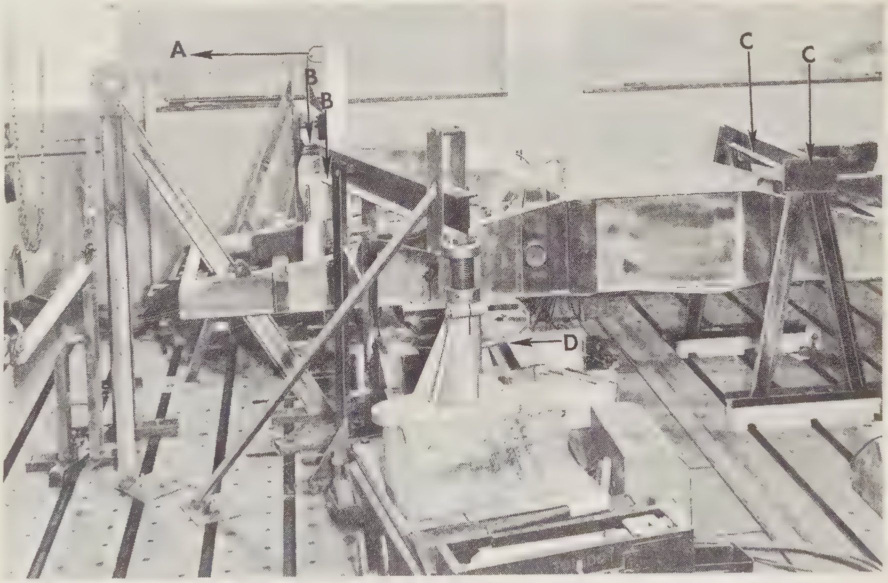


Fig. 5—Shown here is the test set up used to simulate loads caused by braking. The frame is in the same position described in Fig. 4. The load applied at point *A* had a magnitude of 9,476 lb and was so positioned as to produce the necessary loads in the upper and lower radius arms, which had imposed loads of 12,879 lb and 8,141 lb, respectively. The load at points *B* was 5,922 lb. Points *C* and *D* represent reactions. The reaction at point *C* was the vertical reaction of the front suspension, which was moved a distance of 23.2 in. to induce the necessary moment from the braking reaction. The reaction at point *D* was the horizontal reaction taken out at the fifth wheel.

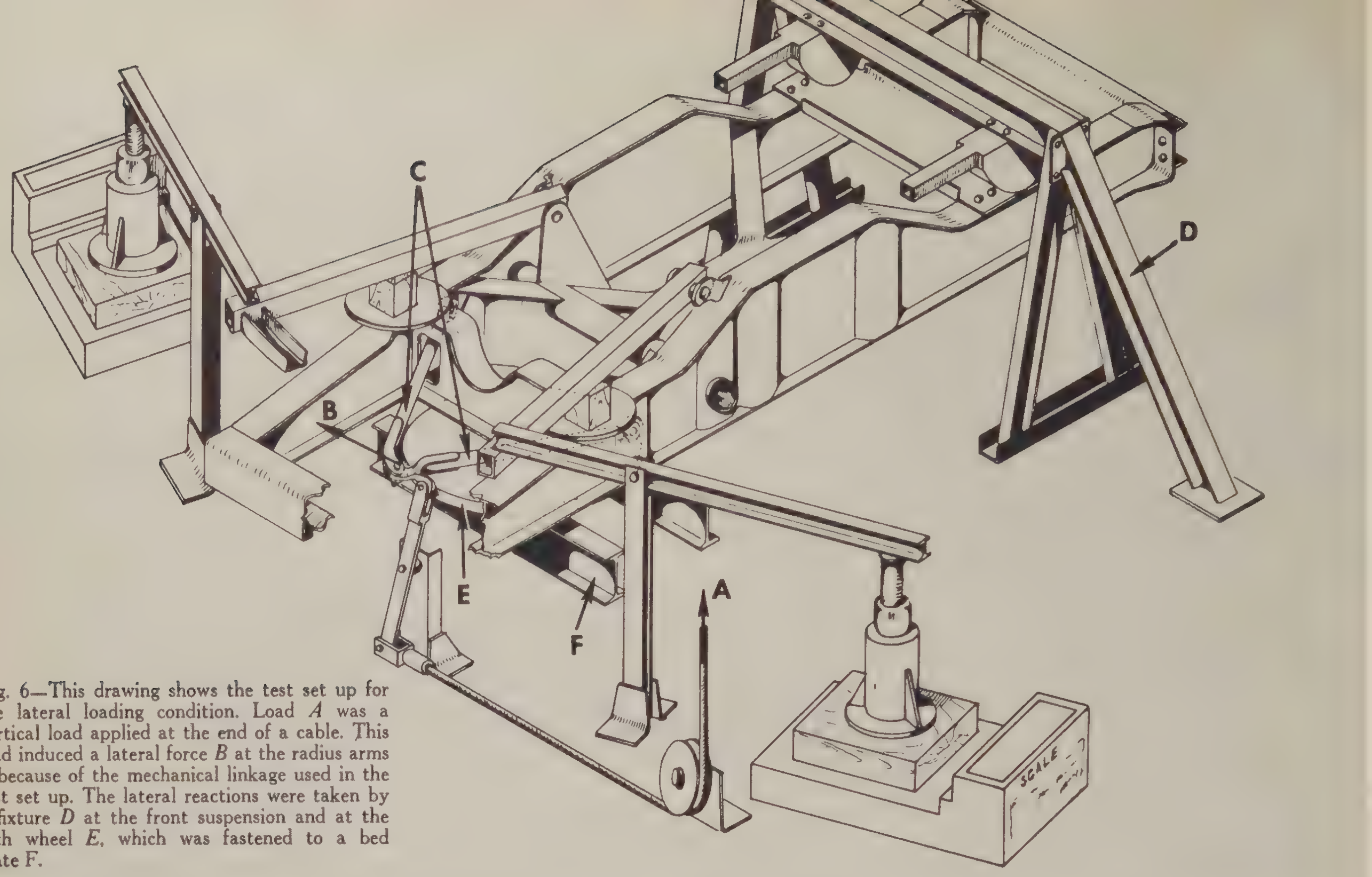


Fig. 6—This drawing shows the test set up for the lateral loading condition. Load *A* was a vertical load applied at the end of a cable. This load induced a lateral force *B* at the radius arms *C* because of the mechanical linkage used in the test set up. The lateral reactions were taken by a fixture *D* at the front suspension and at the fifth wheel *E*, which was fastened to a bed plate F.

highway tractor, since the user often has specialized requirements which control tractor wheelbase specifications.

Test Frame Subjected to Various Load Conditions

The design of the fabricated I-beam frame was so radically different from the conventional channel-type highway tractor frame that a rather elaborate testing program was advisable.

A test frame was subjected to the following load conditions:

- 3g vertical loading
- 1g vertical loading with 0.8 coefficient of friction brake stop (taking into account weight transfer)
- Torsional loading
- 1g vertical loading with 0.5g lateral loading.

Vertical Loading

The 3g vertical loading simulated conditions occurring on rough roads. Experience gained driving on the Belgian block road at the GM Proving Ground, Milford, Michigan, indicated that loads up to 1.5g occurred often enough to be considered in designing for fatigue stresses. At a 1.5g loading, therefore, no stresses were allowed to exceed that recommended for the fatigue endurance limit of the material used.

A 3g loading, as might occur on a severe bump, does not happen often enough to be considered a fatigue type load. The stresses for this condition, therefore, were considered satisfactory if they stayed below the yield strength of the material.

Vertical Loading With Brake Stop

For the braking test a coefficient of friction of 0.8 was used. This coefficient is above normal for a sustained brake application. Experience indicated that a coefficient of 0.6 is about average for a severe brake application. It was felt that the 0.8 coefficient would take into account a condition where the brakes were applied while at the same time striking a hole in the road.

Braking occurs frequently, but seldom so severely as specified in this yield strength loading condition. Therefore, a 1g vertical load with a 0.25 coefficient of friction was selected as the criterion for that condition which takes place often enough to be considered of a fatigue nature. Stresses induced at this loading were kept below the fatigue endurance limit.

Torsional Loading

The torsional loading test simulated a condition where one wheel drops into a hole or another condition where one wheel climbs a curb. Neither of these conditions occur frequently enough to cause fatigue failure. Stresses permitted under this loading, therefore, were within the yield strength of the material.

Lateral and Vertical Loading

Lateral loads developed in a vehicle result from cornering at a high rate of speed, or they can be induced by sliding laterally on ice and then encountering dry pavement or striking the road curb. Although the conditions may seem somewhat extreme, the loading used is the lateral force necessary to overturn the vehicle.

From calculations plus information obtained on roll, or side sway, tests conducted at the GM Proving Ground on other vehicles, a design criterion of 0.5g lateral loading and 1g vertical loading was selected as a condition which would indicate the structural needs of the frame and yet not penalize it for weight. Since this type of loading was not of a fatigue nature, the stresses for this condition were allowed to approach the yield strength of the material.

Test Conditions Simulated Frame Loads

It had been established in the early stages that the front axle of the tractor was to have an 11,000-lb static load capacity and the rear axle an 18,000-lb static load capacity. The rated gross combination weight was to be 61,000 lb. Knowing the design loads, therefore, the loads on the axles for the 3g vertical loading became 33,000 lb for the front axle and 54,000 lb for the rear axle.

Although the axle loading determination had been simple, it was necessary to make a study to establish how the 3g vertical loads could be applied to the test frame to simulate as closely as possible the actual shear forces and bending moments encountered by a running vehicle. Since the actual shear forces and bending moments were caused by both concentrated and distributed loads which could not be simulated readily on test, it was decided for test purposes to use no more than two or three concentrated loads. Calculations indicated it would be possible to simulate actual shear and bending. For the 3g vertical loading test, the frame was placed in an inverted position. Loads were applied at two points to simulate the shear and bending moments obtained from the more complex running loads (Fig. 4).

Before an analysis could be made of the loads to which the frame would be subjected by braking, the physical dimensions of the trailer had to be selected. These were as follows:

- Load on tandem axle of trailer = 32,000 lb
- Unsprung weight of trailer tandem axle = 3,000 lb
- Trailer length = 35 ft
- Kingpin setting from front of trailer = 36 in.
- Centerline of trailer axle from rear of trailer = 100 in.
- Height of center of gravity of trailer = 80 in.

The maximum fifth wheel setting was selected as 23 in. forward from the centerline of the rear axle. This setting provided sufficient pay load transfer to fully load the front axle. The frame was designed to withstand the bending moments induced by this load transfer.

For the 1g vertical loading test with 0.8 brake stop (Fig. 5) it was necessary to apply horizontal forces to the front and rear suspension; also, a moment had to be added to the frame where the front independent crossmember attached. The same problem was encountered with this loading condition as with the 3g vertical loading condition in that the shear and bending moment diagram for the test had to simulate as closely as possible the calculated shear and bending moment diagram. This condition was satisfied by adding one more external force to those used for the 3g vertical loading condition.

The 0.8 brake stop test, taking into account weight transfer, increased the front axle loading from a static condition of 11,000 lb to 22,732 lb, an increase of 105 per cent. The rear axle loading of 18,000 lb for the static condition decreased to 14,229 lb, a decrease of 21 per cent.

The vertical loading for the brake stop condition was much less than the 3g vertical condition, but the frame was designed to withstand the additional horizontal forces and moments induced along with the vertical forces.

In conducting the torsional loading test on the frame, a 1g load was applied to the frame in the same manner as for the 3g loading condition. The load then was removed from one of the rear loading positions. This loading condition simulated both front wheels and one rear wheel on the ground with one rear wheel free. Another torsional loading test was to anchor the frame at the rear air spring supports and apply torque at the front suspension location. This set up also was used to measure the torsional rate of the frame.

For the lateral load test (Fig. 6) the frame remained in an inverted position, but the fifth wheel was secured to the bed plate to resist horizontal as well as vertical movement. Lateral movement also was resisted where the front suspension crossmember attached to the frame.

The 1g vertical load and the 0.5g lateral load were applied as follows:

(a) A force of 17,600 lb was applied at the aft end of the rear suspension lower arms, where they attached to the axle (same loading point as for the 3g vertical load).

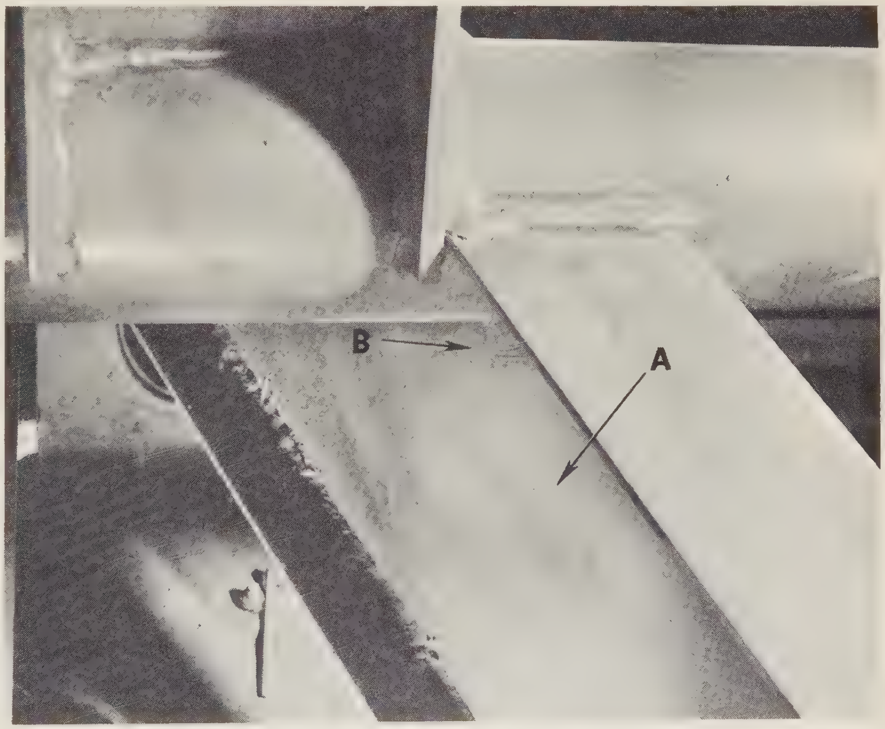


Fig. 7—The brittle lacquer technique, using ionized powder sprayed on the lacquer to intensify stress cracks, made it possible to photograph all major stress concentration crack patterns for permanent record. The large crack pattern *A* shows buckling in the center of the web. The crack pattern at *B* is a stress concentration. Both crack patterns appeared at the ultimate lateral loading condition. Since the stresses in these regions were below the yield strength of the material, and the conditions at which the stress cracks occurred could not be considered of a fatigue nature, no design changes were made in the structure.

There resulted an upward reactive force of 22,800 lb at the fifth wheel and a downward reactive force of 5,200 lb at the front suspension crossmember

(b) A lateral force of 8,073 lb was applied horizontally at the intersection of the upper arms of the rear suspension. This force was reacted by a horizontal force of 10,257 lb at the fifth wheel and a 2,184-lb force at the front suspension crossmember location

(c) When the lateral load was imposed, 97 per cent of the vertical loads were carried on one side of the frame.

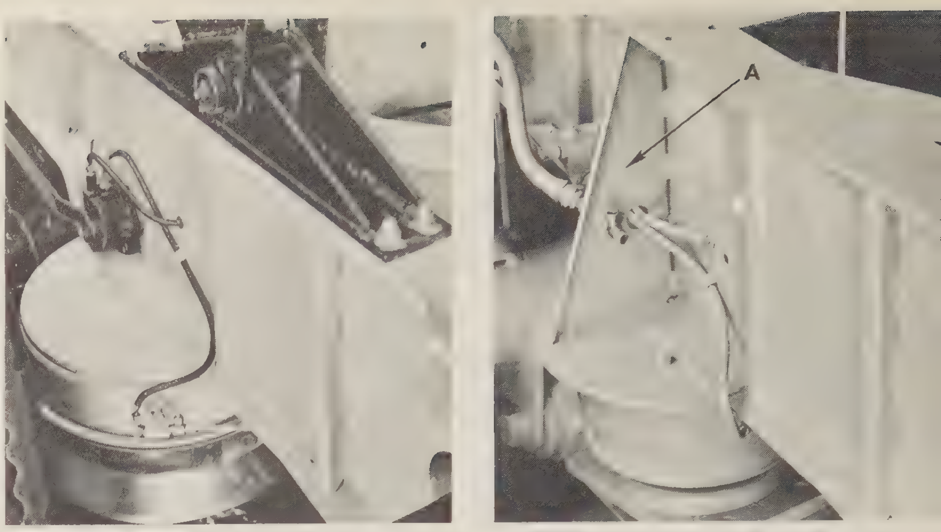


Fig. 8—Certain design changes resulted from static tests performed in the laboratory on the frame. For example, it was found that high stresses were caused by the overhang of the rear air spring relative to the centerline of the frame side rail (left), which resulted in local torsional deflection of the bottom flange of the frame. To eliminate this deflection a brace *A* was added (right).

Brittle Lacquer and Strain Gages Used for Stress Analysis

At the start of the laboratory testing program, the test frame for the series 8000 tractor had only the necessary web stiffeners which were necessary as brackets for supporting such components as the fuel tanks, air tanks, and front independent suspension crossmember. It was decided that if additional stiffeners were needed their position could best be chosen during testing of the frame under load conditions by applying the brittle lacquer technique to locate the region of web buckling and then placing a stiffener in such a manner as to resist the buckling.

The brittle lacquer technique was used throughout the frame test program for a qualitative analysis of the stresses and to determine the location of stress concentrations. Past experience indicated that for a part having the size and intricate shape of the frame it would be impossible to calculate the exact region of maximum stress, or the direction of stress.

When the brittle lacquer was applied to the test frame, cracks formed in the lacquer due to strain in the metal. The cracks formed at 90° to the direction of stress. An ionized powder was used to intensify the stress coat cracks. The application of the powder involved applying a special penetrant to the lacquered test piece, then superficially drying the surface which left the penetrant in the cracks, and finally blowing the ionized powder over the part. The powdered particles, which obtained an electrostatic charge when blown from a special gun, were attracted to the cracks. The use of the ionized powder made a clear photograph of the crack pattern possible. On the test frame, all major stress concentration crack patterns were photographed (Fig. 7).

For a quantitative analysis, strain gages were used. To obtain a true reading the strain gages were applied at 90° to the direction of the crack pattern. A recorder was used to run a tape record of each increment of loading for each load condition. A plot was made on graph paper of load versus stress for each strain gage. Plotting of the stresses indicated if there was a sudden increase in the measured stress, if some portion of the metal adjacent to the gage had yielded, and if a part to which the strain gage was attached had to carry additional loading.

Design Changes Resulted From Static Tests

The results of the 3g vertical loading condition showed high stresses in the area where the rear air spring attached to the frame. These high stresses were diagnosed as being caused by the overhang of the air spring relative to the centerline of the frame side rail (Fig. 8—left). Because of this overhang the bottom flange of the side rail tended to deflect torsionally. A brace was added to eliminate this local torsional deflection of the bottom flange (Fig. 8—right).

The 1g vertical loading condition with the 0.8 coefficient of friction brake stop indicated high web stresses in the area where the front independent suspension crossmember attached to the frame side rails. These stresses were caused by the crossmember trying to deflect, since all braking loads were transmitted from the crossmember to the side rail through brackets at the flange. As a result, the web thickness in this area was increased to 0.1046 in.

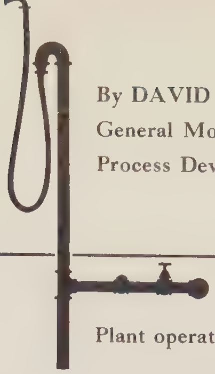
Neither the torsional nor lateral load tests indicated a weakness in the frame structure.

Summary

The I-beam section fabricated frame for the series 8000 GMC highway tractor was designed and developed to meet the specific objective of a lightweight, high strength frame. That this objective was achieved is indicated by the fact that the new frame weighs approximately 400 lb less than a comparable channel frame used on a tractor in the same weight class. The design approach used gives the frame 27.8 times more torsional stiffness and 1.6 times more beaming stiffness than a conventional channel frame assembly. The I-section construction gives a frame torsional rate of approximately 8,350 lb-ft per degree of twist, as compared to approximately 600 lb-ft per degree of twist for conventional channel frames.

Basic fundamentals of mechanics and strength of materials plus the application of present day techniques for strain measurement provided engineers with the basic tools for proving the design. As a check on the static tests performed in the laboratory, tests were conducted on a completed tractor on the Belgian block road and the truck durability route at the GM Proving Ground, Milford, Michigan.

Applying Water Conservation Methods in GM Plants



By DAVID MILNE
General Motors
Process Development Staff

Water conservation in manufacturing plants is important both for economical reasons and for safeguarding the community's existing water supply. Future plant operations have become more dependent upon the availability of water and its proper use in the plant. General Motors has recognized the importance of water conservation in heavy manufacturing operations and has set up programs designed to alleviate water shortages and overcome unnecessary expense through employe education, preventive maintenance, and equipment design. Water conservation can be applied to three areas of manufacturing activity: cooling water applications, use of water for heating, and in general processing where water comes in contact with the product.

Plant operations can be improved through water conservation programs

MAN'S progress through the centuries has depended upon his utilization and exploitation of the water resources of the earth. As industries have been forced inland from sites near ocean shores and waterways, the availability of water has diminished. Construction of new plants and expansion of old ones also has taxed existing water supplies.

The necessity for conservation of water in its operations became increasingly apparent to General Motors after World War II. Water supply was dwindling and many areas and communities were hard pressed to meet the demands of industry. Plans for new plants were decidedly affected by considerations of water supply.

Discussion of the situation during meetings of the General Motors Plant Engineers Committee emphasized that conservation of water was an important area in future plant operations, not only for economy, but also for maintaining good relations with communities.

Plant engineers then developed programs for water conservation that have made progress in this area. In 1957, which can be taken as a reasonably good year for industrial operation, General Motors used 72 billion gallons of water in its plants in the United States and Canada. This quantity would have been much greater had it not been for determined efforts for conservation by the plant engineers.

Organizing a Plant for Water Conservation

Typical steps in organizing a plant water conservation program include:

(a) A general survey of water use in the plant. This should be done by the use of meters or any other water measuring device, rather than by estimate
(b) The establishment of the minimum water flow necessary for each piece of equipment
(c) The education of plant personnel to recognize the need for water conservation and to understand the methods of cutting down on water use. This includes providing them with information on minimum necessary water requirements for equipment
(d) Substitution of another cooling media such as air
(e) Substitution of a cooling method requiring a minimum of water, such as refrigeration in place of a cooling tower
(f) Recovery and reuse of water. The possibility of reuse in the same process should be considered, also any conditions affecting reuse for other processes
(g) Reduction of quantities used. This probably represents the most practical area of water control and might include the establishment of automatic control as well as manual control over equipment, the establishment of tight preventive maintenance programs, considerations of equipment design or process rearrangement, and the establishment of technical control over the process itself.

For most heavy manufacturing it has been found that these steps toward water saving can be applied in three broad areas of activity. These are:

- In cooling water applications
- In the use of water for heating
- In general processing which makes use of water in contact with the product.

Conservation in Cooling Water Applications

The cooling processes used in General Motors include those necessary for the operation of such equipment as welding machines, die casting machines, rectifiers, plastic molding machines, and air compressors. They would also include water for heat exchangers for control of temperature of processes, such as electroplating and anodizing.

Recirculating Systems

Most of the General Motors plants are using recirculating water systems for the supply of water to cooling equipment. Besides cutting down the amount of water necessary for this operation, this procedure minimizes maintenance and operating problems due to accumulation of scale and corrosion deposits in the equipment. Water used on a once-through basis cannot be chemically treated economically for the control of these deposits. The use of the recirculating system provides the opportunity to apply this type of control.

An example of one recirculating method is the installation of intermediate heat exchangers in a closed system in which the water used for cooling a process is obtained from a demineralized supply or is steam condensate. The cooling water for the heat exchanger may be treated city or well water and is circulated through a spray tower. This system may appear to be extravagant, with respect to the investment involved, but the reductions in equipment failure, downtime of productive equipment, and maintenance expense more than compensate for the added investment and utilities cost.

One of the General Motors plants, in

reviewing the value of cooling towers to its operation, pointed out that in 1957 nearly two billion gallons of water were supplied by the towers, and that because of this it was only necessary to draw 83 million gallons from wells for makeup and drinking water. This represented a ratio of 24 to 1. This is particularly significant in this plant because of the increasingly critical situation in water supply from the wells. The water table has been dropping noticeably and conservation measures were necessary to cope with the decreasing availability of water from these wells. While the ratio given above represents the yearly average, it is of interest that during August of the same year when maximum cooling water was required, the ratio of cooling tower water to well water supplied to the plant was approximately 41 to 1.

A few years earlier, and before an additional sewage charge went into effect, the ratio of cooling tower water to well water was only 6.5 to 1, and well water usage was four times the present. This illustrates a point frequently made that installation of conservation equipment often permits the plant to save money as well as making more water available to the community.

Heat Exchangers

Plant engineers have pointed out that in their experience one of the most uneconomical units in a water system is the undersized heat exchanger. It can easily use from 5 to 10 times the water that a properly sized exchanger would use. This not only increases the operating costs but eventually requires increased investment in pumps and water lines. The greatest occurrence of undersized coolers, according to the engineers, are those supplied as auxiliaries along with purchased equipment. One of the General Motors Divisions has established the following specifications in an attempt to eliminate the use of undersized coolers on equipment requiring water cooling:

> "Cooling equipment must be capable of supplying adequate cooling with water inlet temperature of 85°F and exit water temperature of 95°F. Cooling water is available at 50 psi and back pressure, 20 psi. Water has 35 grains hardness."

Welding Equipment

Another area in which water conservation has proven beneficial is in the reduction of water usage in welding machines. This has been accomplished in various ways in addition to installation of recirculating systems. For instance, mechanical refrigerating systems have been used instead of water cooling.

Other successful techniques for welding operations have been in the use of thermostatically controlled valves particularly where mercury arc rectifiers are used, and in the use of water valves which are synchronized with the operation of the welding presses. Each of these control devices, obviously, makes sure that no water is used while the equipment is not in use and takes control of water flow out of the hands of the operator. Thermostatic control of cooling water to air compressors has also been successful.

Coolant Temperature Control

One additional example of water savings in a cooling application was in a process involving the honing of cylinders which required accurate size control. This meant that the coolant used on the honing machine had to be kept within very close temperature limits. The plant decided that an integral mechanical refrigeration unit should be used on each machine rather than water coils in the coolant reservoirs. The reasons for this choice were: (a) the refrigeration equipment was self-contained and compact, (b) lower plumbing costs would result, and (c) water was conserved by using this equipment.

Heating Operations Provide Opportunities for Savings

The next area of water conservation, that involved in heating operations, presents somewhat less opportunity for savings. In General Motor plants this is mainly the recovery of steam condensate, both from high pressure lines and from the coils used in process heating.

Condensate Returns

In almost all cases in General Motors plants, condensate from coils used to heat a processing solution is not returned to the power house as boiler feed makeup. This is because of the possibility of contamination of the condensate by the development of leaks in the coils and subsequent loss of the processing solution into the condensate lines. To some extent this can be controlled by the use of conductivity measuring equipment installed in the lines returning from these operations and several of the plants have done this.

Steam Condensate

Steam condensate can be recovered and used as process rinse water and for solution makeup. As rinsing water it has the obvious advantage of being free from minerals and allows the parts being rinsed to dry without spotting. As a solu-

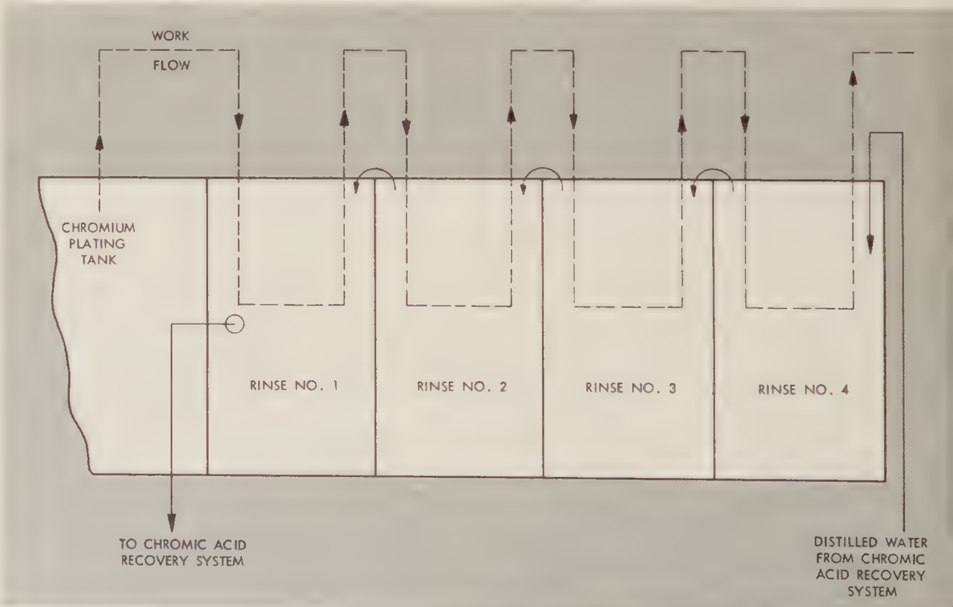

WORK
FLOW
CHROMIUM PLATING TANK
RINSE NO. 1
RINSE NO. 2
RINSE NO. 3
RINSE NO. 4
TO CHROMIC ACID RECOVERY SYSTEM
DISTILLED WATER FROM CHROMIC ACID RECOVERY SYSTEM

Fig. 1—An effective means for conserving water used in rinsing operations is the application of the counter-flow rinse system. The more concentrated rinse water from tank No. 1 is withdrawn to a vacuum evaporator system in which chromic acid is concentrated and returned to the chromium plating tank. Distilled water recovered from this recovery system is introduced into rinse tank No. 4 and flows by stages through the other rinse tanks in the system. Work flow is always counter to rinse flow so that the cleanest rinse water is used last.

tion makeup water, its high purity avoids the introduction of contaminants into processing solutions and helps to extend solution life, thus adding to its value as a water conservation measure.

Impure Condensate

Steam condensate, however, is not always absolutely pure water as most power plant operators will testify. Boilers operated at high ratings, even with well maintained separators, have an annoying habit of entraining boiler water with its high solids content along with the steam being supplied to the plant. Condensation of the steam, of course, entraps these boiler water droplets and produces a certain amount of contamination.

In addition, if the steam is used to drive equipment such as air compressors, the exhaust steam obtained from these pieces of equipment and normally distributed to the plant for process heating usually contains noticeable amounts of steam cylinder oil. Obviously, condensate contaminated with this oil would be a poor choice for rinsing operations, particularly where the rinsing process is to be followed by some finishing technique such as electroplating or painting.

Control of Rinsing Allows Savings in Processing Waters

Another lucrative area in water conservation lies in the control of water used for processing. This is particularly the case where extensive rinsing operations are performed.

Counterflow Rinsing

One of the most effective means for reducing water usage in rinsing operations in General Motors plants is the counterflow principle, in which water is added to the last tank in a series of rinse tanks, and allowed to cascade successively into the preceding tanks in the series (Fig. 1). It has been estimated that this technique permits satisfactory rinsing with only one one-hundredth of the amount of water needed for a single rinse operation.

Rinse Control by Conductivity

Another technique used by the plants is in the control of the amount of water used by the conductivity of the rinse water. Conductivity measuring equipment is installed in the rinse tank (Fig. 2) and set in such a way that it will allow fresh water to be introduced to the system only when the rinse water arrives at a predetermined level of conductivity from salts being washed from the parts.

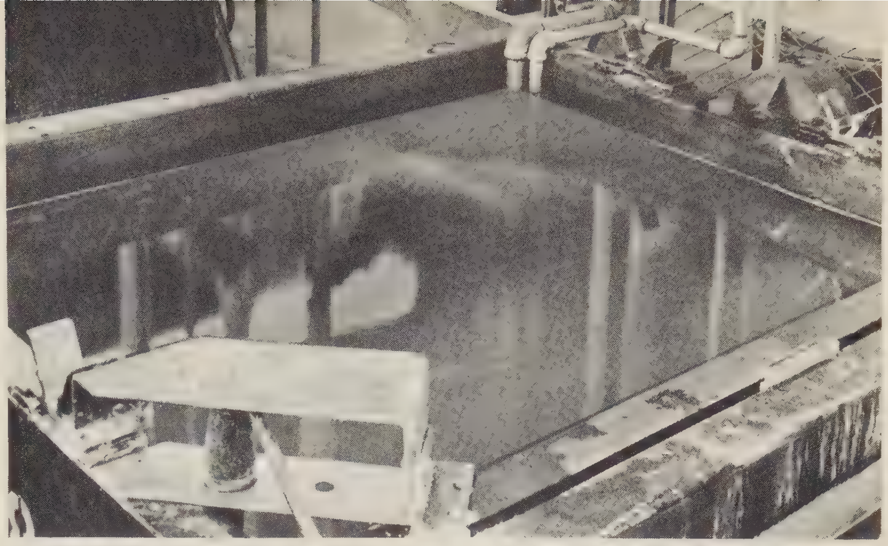


Fig. 2—A conductivity measuring system installed in a plating rinse tank can be applied to the control of water usage. Shown here is a typical installation. The foreground shows the mounting of the sensing electrodes. The meter and controlling devices are not shown but are located nearby. As more salts from rinsed parts are left in the water, the conductivity, in turn, goes up. The control system is set to allow the addition of fresh water to the tank (through a pipe in the background) only when the conductivity rises to a selected level.

One of the Divisions has been quite successful in treating a cyanide bearing rinse water in the rinse tank and thereby accomplishing a waste treatment job as well as minimizing the water use (Fig. 3). Figures from the plant on the operation of this tank show that the amount of rinse water used was reduced from 15 gpm to one gpm.

Rinse Water Reduction

In some plants some success has been achieved by substituting air blow-off systems for water rinses in the initial stages of rinsing, and in the use of steam as a rinsing agent by allowing the steam to condense on the surface of the part. Very finely divided fog rinses have been used in some operations to apply a minimum quantity of rinse water to the parts.

The perennial problem of manual control of rinse water has been solved in several General Motors plants by the use of a simple control valve which allows only a small volume of water to pass through an orifice, but which assures constant volume regardless of the pressure in the water system. Fixed orifices have been used to achieve somewhat the same results before but have the disadvantage of allowing variable quantities of water to pass through, depending on the pressure.

One simple control measure used in one of the plating plants was a master valve in the water main supplying the rinse tanks so that at the end of the operating shift all rinse water could be turned off at one location rather than at each rinse station.

In one plant operating in a locality with a high water cost and using spray rinsing, the size of the orifice in the spray nozzle was reduced from ¼ in. to ⅛ in. with a resulting saving in water usage.

Enclosed Rinsing Systems

In another plant, a plating operation used about 400,000 gallons of water per day for rinsing operations, all of which was run to the sewer. A rinse recovery system (Fig. 4) was installed next to each tank containing toxic chemicals. The subsequent final rinses contained so little contamination that the water was returned to the cooling tower for reuse in other operations.

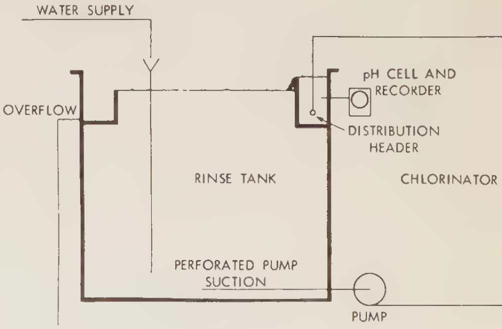


Fig. 3—This schematic diagram illustrates a continuous rinse chlorination system used by one GM Division to destroy waste cyanides in the rinse tank by application of chlorine gas. Rinse water is continually withdrawn by the pump and passed through a chlorinator, then returned to the rinse tank.

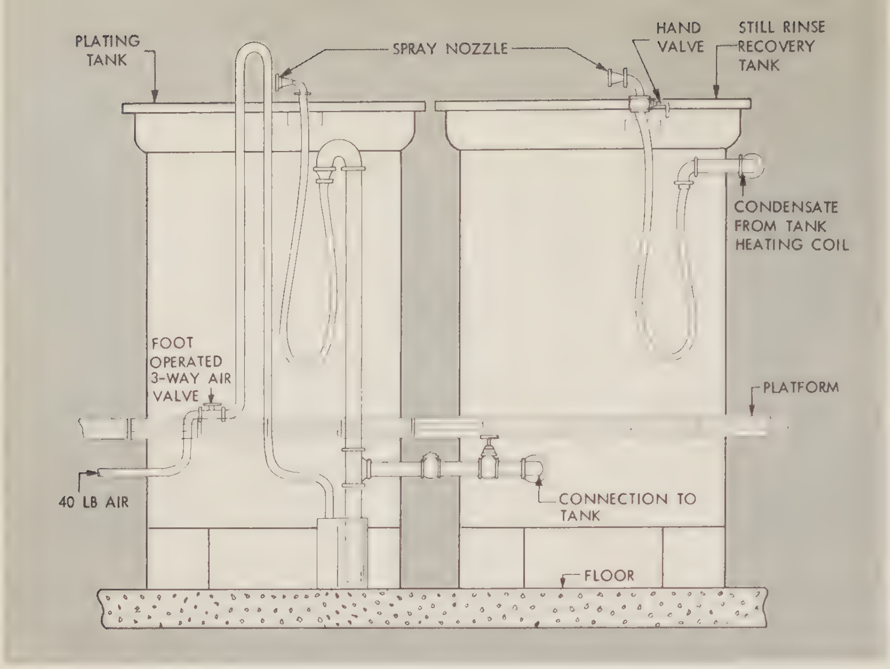

PLATING TANK
SPRAY NOZZLE
HAND VALVE
STILL RINSE RECOVERY TANK
CONDENSATE FROM TANK HEATING COIL
FOOT OPERATED 3-WAY AIR VALVE
PLATFORM
40 LB AIR
CONNECTION TO TANK
FLOOR

Fig. 4—An appreciable reduction in rinse water needed for plating operations was obtained by installing a rinse recovery system at one GM Division. As the plated parts are raised above the plating tank, they are sprayed with water from the still-rinse tank. They are then dipped into the still-rinse tank and on emerging are sprayed with condensate from the plating tank heating coils. This recovery rinse system reduced the rinse water use by one half, eliminated the need for a costly rinse water treating plant, and reduced the cost of chemicals needed for plating.

Additional Areas for Savings

Another processing area which responds to conservation methods is one using emulsifiable oils for cutting operations. Attention to cleanliness in these systems and removal of bacterial contamination extends solution life considerably, and in doing so eliminates the need for discharge of the solution and subsequent makeup with fresh water. Some of the plants have been using the same soluble oil in a circulating system for a period of years.

One additional area which should not be overlooked is in the reuse of effluent from industrial waste treating plants. These effluents could certainly be used for quenching and primary rinsing and for other uses requiring water as a means of transporting solid materials such as in ash handling systems.

Putting Water Saving Programs into Operation

These examples illustrate some of the techniques used to conserve water in cooling water applications, heating operations, and in processing water applications. However, there are other methods of conserving water that are equally important. For example, one General Motors plant established a five man committee which developed an effective water conservation plan through:

- Employe education of the need and methods of saving utilities
- Preventive maintenance on all utility handling equipment
- Designing utility conservation into new equipment.

Another plant centered its conservation program around installation of recirculating water systems, automatic control of water supply to individual machines, and careful techniques for the recovery and return of steam condensate. The program saved the community over 360 million gallons a year. Average water use per month at this plant has remained the same in spite of the doubling of the plant's floor space resulting in increased domestic and sanitation usage, increase in water consuming processes and equipment, and a 100 per cent increase in boiler capacity and steam production.

Another division of General Motors initiated a steam control program tailored to plant operation that produced a water saving. Careful control of steam usage during second and third shift operations and on weekends resulted in a noticeable reduction in the amount of steam demand from the power plant with a consequent saving not only in water used for makeup but in the coal consumed by the power plant.

A problem that was not primarily water conservation, since ample supplies were available, but was one of limited sewer capacity in the municipal system, faced another plant. A planned approach to water conservation was started with a survey on all water using equipment to determine the proper flow for the prescribed job and how process waters might be segregated to the proper sewer system. Correct water flow was established from engineering data and from on-the-job observation. Once established, the flow was checked by the daily recording of readings from meters installed on large water using equipment such as plating systems.

The program has been broadened and now incorporates changes in design of equipment as well as simple water reduction procedures. Counterflow rinse tanks and automatically timed sprays have been incorporated in all plating systems. Since 1953 the plant has operated a demineralizing system for removal of contamination from plating rinse water. This water is reused in the plating process and is also supplied to the power house as makeup water for the boilers.

Since 1954 the number of plating conveyors has more than doubled in this plant but sensible design of equipment resulted in no increase in water use. Hydraulic oil coolers have been completely redesigned to use minimum amounts of water and automatic control systems for makeup water in washers have been installed.

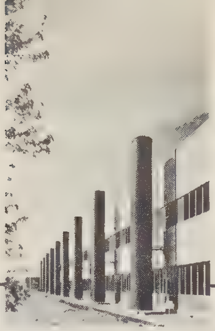
In 1957 eleven additional die casting machines were installed but the use of closed water recirculating systems prevented any increase in water consumption for the plant.

In spite of the continually increasing installation of water using equipment and expanding floor space in the plant, water consumption for this operation is steadily declining. Constant attention to detail in water conservation and the development of a water savings attitude in the plant personnel dropped water usage from an average of 2,300,000 gallons per day in 1949 to the present figure of 800,000 gallons per day.

Summary

From the actual plant experiences cited, it is evident that close attention to control of water in the plant can result in greatly lowered consumption. This benefits both community and manufacturer from three standpoints—making more water available to others, reducing the load on sewer systems, and lowering the cost of manufacturing.

The Chevrolet Engineering Laboratory—a Facility for Improved Vehicle Development



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Division

How the automotive laboratory functions in product design

The growing importance of development and testing in automotive engineering is one of the reasons for the construction of the Chevrolet Engineering Center. An important facility of the Center is the laboratory where a variety of tests are conducted on the complex components of the latest automotive models. A review of the methods used during the testing of Chevrolet automatic transmissions reveals the scope of operations the laboratory must undertake in order to supplement the findings of the GM Proving Ground. While final performance must still be measured under actual vehicle driving conditions, the quantitative data acquired during the laboratory testing of both the components and the complete transmission provides a better basis for product improvements.

TODAY'S automobiles last twice as long and have an average lifetime mileage that is four times greater than the vehicles of 30 years ago. An important factor contributing to this progress is the growing excellence of the test and development techniques of modern automotive engineering departments.

The creative phase of engineering has changed little over the years. New mechanical designs are still fundamentally the product of men's minds. But considerable change has taken place in the developmental and test stages of automotive engineering.

In 1926, the Chevrolet Motor Division constructed its first experimental laboratory in Hamtramck, Michigan. Before then, testing facilities had existed only in the various plants. A new laboratory of 13,000 sq ft was built in 1938 to provide more and better testing facilities for the vehicles that were rapidly becoming more complex. Within 15 years it was obvious that this laboratory was no longer adequate to handle Chevrolet's development program. From 18 engineers and 75 draftsmen of 30 years ago, Chevrolet Engineering in 1958 had grown to 420 engineers and over 400 draftsmen.

To meet the demands of the extraordinary increase in engineering activity, long range plans were fulfilled in 1955 with the construction of the Chevrolet Engineering Center, adjacent to the GM Technical Center, north of Detroit. Here are located the requisites of product engineering—management, design, drafting, experimental shops, laboratory, and supporting operations.

Since scientific car design makes complete test facilities imperative, one wing of

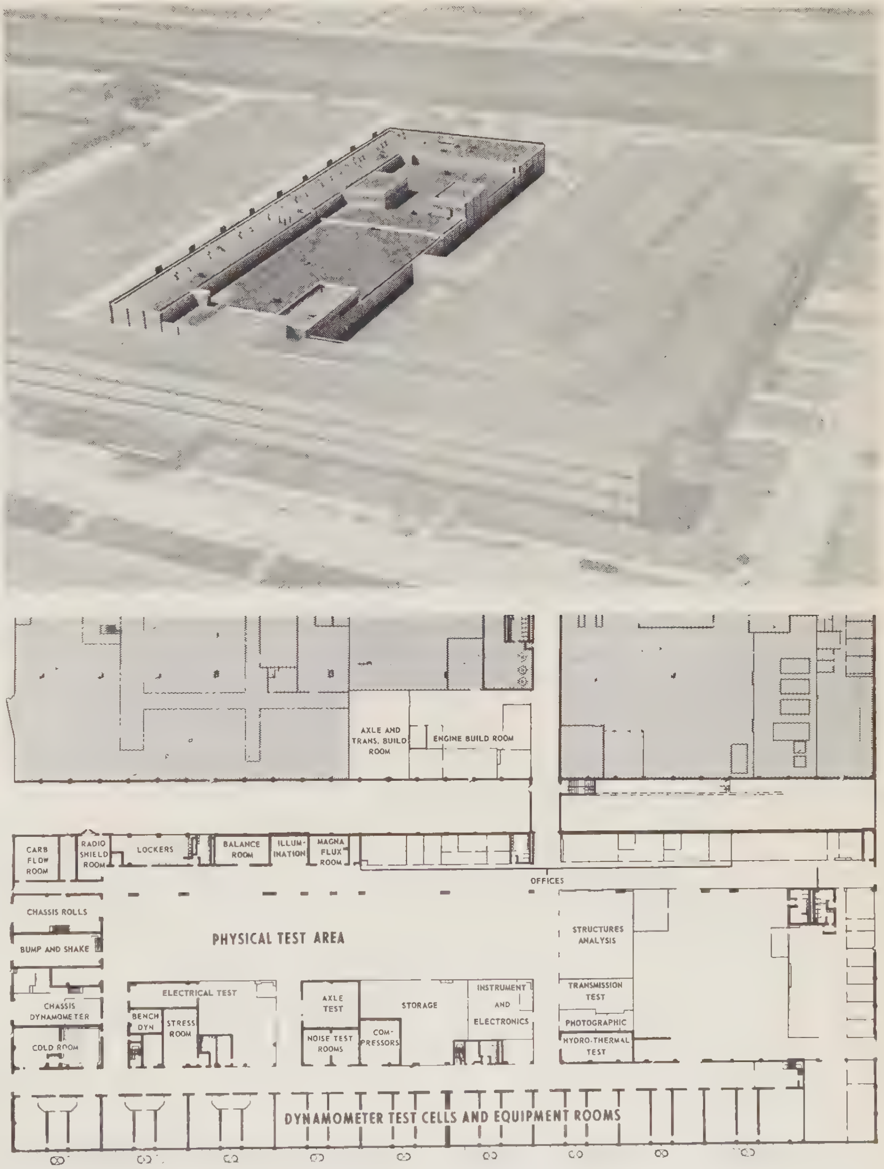

Fig. 1—Location of the principal areas of the Engineering Laboratory and its relation to the other buildings of the Chevrolet Engineering Center are shown above.

the Center is assigned to the laboratory (Fig. 1). It has a working area of 10,000 sq ft, plus a mezzanine. All truck and passenger car programs undergo testing here.

The laboratory is organized under the Experimental Tests Section which also includes Chevrolet's facilities at the GM Proving Ground, all service and experimental test garages, and a planning group. The man in charge of each of these groups reports to an assistant chief engineer who heads the Section.

The laboratory is administered by a director who is a member of the Engineering Department management staff, thus making possible the correlation of laboratory activities with other engineering functions. An assistant director manages the test activities with an administrative group regulating the numerous operational functions.

Work is assigned to the laboratory from the vehicle design engineering groups and from engineering management and supervision. Jobs may vary from testing a body mounting bolt for ultimate strength, to conducting a complete engine development program from the prototype stage to an accepted production version.

The basic responsibilities of the laboratory are:

(a) To evaluate the performance and durability of proposed designs, using established test standards
(b) To establish test standards
(c) To correlate laboratory investigations with both field experience and GM Proving Ground test findings
(d) To supply test data that document and supplement vehicle road tests
(e) To study all vehicle characteristics or problems under controlled conditions
(f) To accelerate test results by duplicating actual conditions more quickly than is possible in normal vehicle use or test driving
(g) To build, adjust, measure, and record all vehicle components before tests, to analyze and record test results
(h) To provide advance test and development before complete assemblies or vehicles are available.

Laboratory Contains Six Areas for Test Work

The facilities of the laboratory are arranged in areas by function, as follows (Fig. 1):

- Physical testing
- Chassis dynamometer and vehicle dynamics
- Engine development and testing
- Transmission testing
- Electrical and instrumentation testing
- Engine, axle, and transmission fabrication.

Physical Testing

The physical test section contains stroking, cycling, and deflection equipment in an area about the length of a football field[1]. Approximately 60 pieces of test equipment are located here. Frame-body combinations are tested with slow motion twist equipment that keeps the structure in torsion to a pre-determined load or amplitude (Fig. 2).

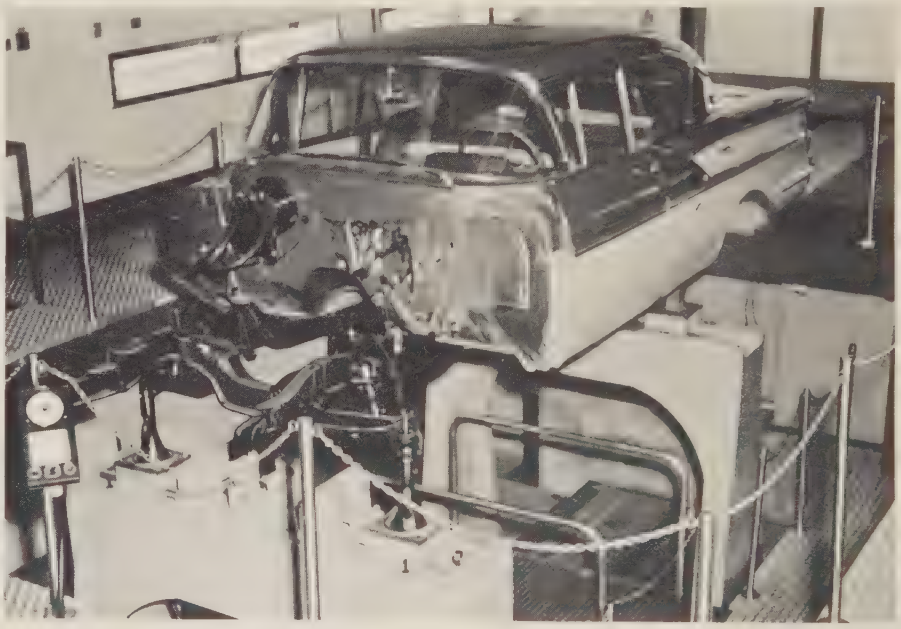

Fig. 2—Body mounts, welds, relative stiffness of components, glass attachment, and door and deck lid fit can be evaluated during repeated excitation of this slow motion twist test.

A vehicle static test room equipped with large surface bedplates allows deflection tests of frames, truck cabs, bodies or complete vehicles of any size or weight. A bump and shake room has equipment that simulates the effect of road vibration on vehicles so that the reaction of components can be probed and recorded. Another room contains chassis rolls having adjustable cam surfaces capable of putting vehicle suspensions through a variety of motions and stresses to check the response of various components.

Chassis Dynamometer

A chassis dynamometer room is used for radiator, transmission and vehicle cooling investigations, vapor lock, and octane requirement studies. It is equipped with a recirculating wind tunnel, chassis dynamometer rolls, and controls for heating the room to 150°F or cooling it 10° below the surrounding temperature. Relative humidity can be raised to 95 per cent or lowered to 20 per cent below existing moisture conditions. With this equipment the engineers can duplicate any road condition including performance on various grades.

Engine Development

Most of the engine experimentation is conducted in 18 dynamometer rooms that have special machinery, ventilation, and safety provisions. Engine dynamometer capacities range from 150 to 600 hp, 450 to 1,950 lb-ft torque, and 6,000 to 8,000 rpm speeds. Each of the rooms is supplied with its own filtered controlled fresh air supply while a tank farm and fuel supply system provide any type of fuel required for an engine test (Figs. 3 and 4).

Cold starting tests and cold weather operation of engines and other components are conducted in a room capable of attaining minus 65°F (Fig. 5).

To determine precise carburetor specifications and to prepare master carburetors with the desired calibration, the

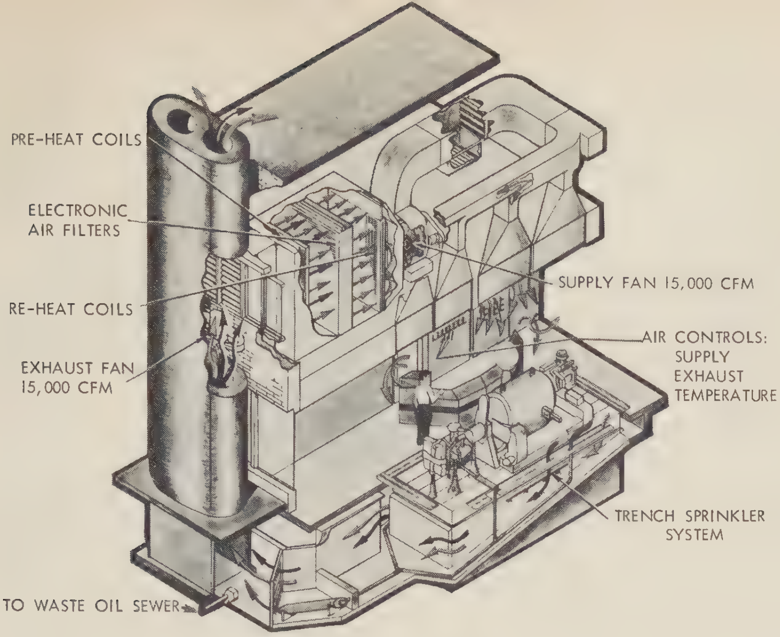

Fig. 3—Outside air enters ductwork in the mezzanine of the laboratory where it is electronically filtered and then flows into the ceiling of the cell at a maximum rate of 15,000 cfm. Air flow and temperature are controlled by each cell's operator. Room air is exhausted through floor ducts. Engine exhaust is water-spray cooled, run through a muffler in the floor trench, and mixed with room exhaust air as it passes through the stacks. All ductwork and blowers are installed in the mezzanine above the cells to make more effective use of space on the first floor test area.

laboratory contains flow benches which provide accurate means for determining the amount of fuel and air which the carburetor should deliver to the engine under all conditions.

Transmission Testing

Since the numerous manual and automatic transmissions for cars and trucks necessitate extensive special development, the laboratory contains rooms with spin-test apparatus, gear checking equipment, hydraulic benches, and cycling machines capable of testing individual parts, subassemblies, or complete transmission assemblies. Equipment for static and dynamic cycling of overrunning clutches as well as freewheeling tests of these units is contained in the hydro-thermal room.

The laboratory also has a transmission dynamometer room with equipment for durability or development cycling of cone or plate clutches, static and dynamic coefficient of friction determination, and thrust washer development. Complete transmissions also are developed and tested for efficiency, durability, and capacity.

Electrical Equipment Testing

A large electrical section contains equipment for investigation, developing, and testing of all automotive electrical devices. A dark room provides facilities for testing interior and exterior car lighting. An instrument and electronic laboratory section permits engineers and technicians to design testing equipment and apply it to the electrical problems that arise. Versatile sound analyzing and measuring equipment, that has proven invaluable in indicating minute noises and vibrations, is located here.

Engine, Axle, and Transmission Fabrication

The final section of the laboratory contains facilities for the assembling and inspecting of experimental engines and transmissions plus equipment for conducting durability, efficiency, deflection, and development tests on axles of all sizes.

Component Parts, Complete Transmissions are Tested

The tests conducted during the development of the automatic transmission exemplify how the facilities of the laboratory are utilized.

Transmission refinement has been accelerated in recent years due to three primary factors:

- The transmission is called upon to deliver more horsepower
- Styling trends have confined it to its original size
- Competition has continuously raised its standards of performance.

To meet this challenge, designers now place greater emphasis on the facilities and methods of investigation. They attempt to replace the educated guess with quantitative measurement.

The basic laboratory approach is to:

(a) Determine what the actual requirements of a new component design should be

(b) Set up test machinery to inflict these requirements on a proposed design and record its performance.

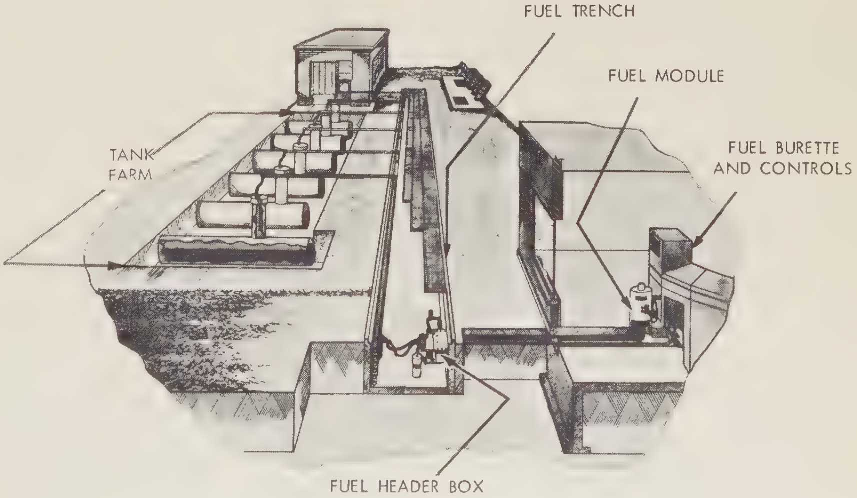

Fig. 4—Tanks containing the fuel supply operate on an aqua-float system with the pressure being regulated by header boxes and pumps in a trench outside each cell. The pumps can be actuated through controls at the operator's position. When the cell is shut down the fuel pressure drops and the supply line drains automatically.

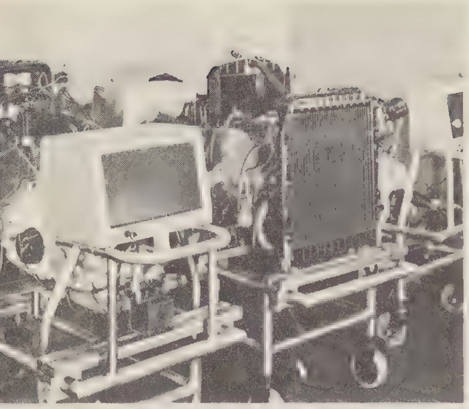

Fig. 5—Engines are mounted on dollies before being wheeled into the cold room where instrumentation is attached. Each engine is a self-contained test unit complete with fuel, electrical, and control systems.

In this first step the needed information is gathered through instrumentation while the test piece is operating in its normal environment. These actual requirements then become the design baselines for both the components and the complete transmission.

Then the engineer must accurately duplicate these normal operating conditions in his test machinery in order to bring the variety of harsh, outdoor realities into the laboratory where he can obtain a quantitative evaluation of their effects. Adherence to this approach ensures close correlation of laboratory test results with performance in a vehicle.

Friction Elements—Static

Evaluation of friction element capacities, both static and dynamic, is one of the laboratory's most exacting assignments. A static torque fixture is used to evaluate the capacity of a clutch such as the plate clutch used in the Turboglide automatic transmission (Fig. 6).

Before the test is run the clutch is installed and operated at maximum pressure and slow speed to burnish and stabilize its surfaces. Plates are soaked in transmission fluid and oiled during the tests.

A series of capacity checks at various operating pressures is made and plotted either as torque capacity versus pressure, or friction coefficient versus unit pressure. The accuracy of these measurements makes the machine useful in determining the effects of various transmission fluids on the coefficient of friction.

Many of the materials tested do not have a sharply defined static coefficient, but rather show an increasing coefficient with increase in slip speed until the dynamic coefficient is reached. This characteristic is of value in that it may permit the designer a smaller safety factor.

Friction Elements—Dynamic

When high energy absorption capacity is needed, as in the Powerglide automatic transmission, high clutch, friction element requirements are more demanding. These materials must perform under extreme pressure and temperature conditions with a predictable coefficient of friction.

The energy capacity required is dependent upon engine torque, kinetic energy change of input system, and shift feel. Because of these requirements and the inherent variations in friction materials, the facilities for careful evaluation are mandatory.

The energy input to a clutch during a shift can be determined from an oscillographic record. The energy entering the transmission during the shift is calculated from the engine torque and input system kinetic energy changes. The energy leaving the transmission during the shift is calculated from the propeller shaft speed and torque. The difference between these two quantities is the approximate energy dissipated in the clutch. The energy quantities thus determined become the basis for the laboratory energy capacity test. In the basic test setup, a dynamic clutch test fixture is used (Fig. 7).

The automatically controlled sequence of events is as follows:

(a) A timer activates a solenoid which directs oil to the drive clutch

(b) Engagement of this clutch accelerates the selected inertia weights and the test clutch drive plates to the test speed

(c) The first timer then releases the drive clutch and a second timer causes a three-second delay

(d) This permits disengagement of the drive clutch. A third timer activates a solenoid valve to supply oil to the test clutch. Any accumulators or orifices are placed between this valve and the test clutch. The oscillographic recorder is started before test clutch engagement, and it records clutch pressure rise and engagement torque against time

(e) The test clutch is released and the cycle repeated.

This equipment can be used to check the dynamic coefficient of new friction materials, to evaluate clutch life at a given energy level, or to determine energy absorbing capacity of the given clutch design. Since the machine accurately measures small torque differences, it also is used to determine the effect of various transmission fluids on the dynamic coefficients.

Thrust Washer Testing

As horsepower has increased, so has the problem of thrust loads imposed by helical gears. A typical thrust washer test fixture places the Powerglide automatic transmission input sun gear in its normal environment so that the effects of lubrication, oil grooves, fluids, materials, and designs may be studied.

Test conditions are determined by plotting a load-speed curve from the torque converter absorption curve. These values are verified by means of a strain gage transducer in the transmission to determine the presence and magnitude of any transient loads.

Using these values, axial load is applied through a hydraulic cylinder. The input sun gear is driven at various speeds up to 4,500 rpm. Friction torque of the washer is measured by a spring scale through a lever arm. Lubricating oil from an external pumping unit is temperature controlled and filtered.

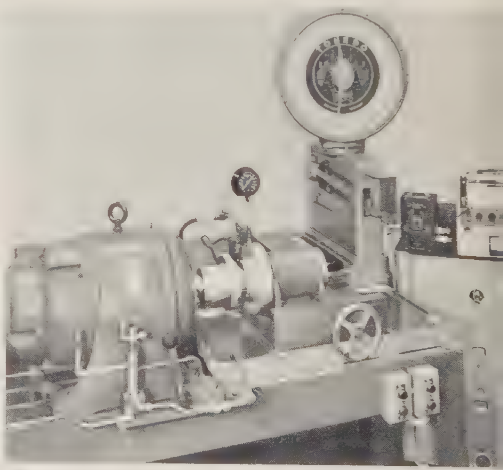

Fig. 6—This equipment is used for evaluating the static torque capacity of a clutch. At the left is a large gear reduction unit driven by a small variable speed motor that allows a variety of slip speeds ranging from 0.3 to 1.4 rpm between the driving and driven members of the clutch. A two-foot torque reaction arm, cradled in needle bearings, bears against a load cell on a dead weight scale. The load cell feeds information to the *X-Y* recorder on the right to provide a plot of torque versus degrees of rotation, while the scale gives a nominal check of torque capacity at a fixed slip rate.

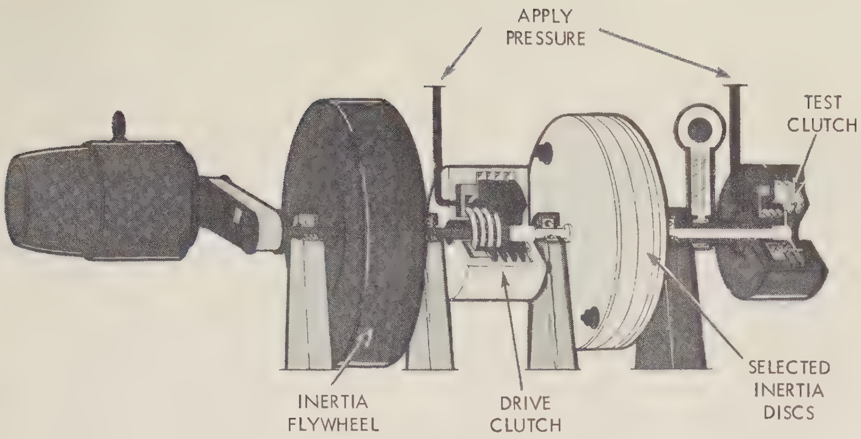

Fig. 7—Shown schematically above is a diagram of a dynamic clutch test fixture used in the Chevrolet Engineering Laboratory for transmission clutch testing. A 10-hp motor continuously drives a large flywheel and the input members of a clutch. With this clutch applied, selected inertia weights are brought up to a predetermined speed. After the drive clutch is released, the test clutch is applied at a controlled pressure rise. The dynamic torque reaction is recorded on an oscillograph through a strain gage transducer on a fixed output shaft. Inertia weights and speed are selected to duplicate the kinetic energy previously determined in an instrumented car. The apply rate of the test clutch also is established by "in car" measurement of the rate at which this energy is absorbed under actual operating conditions.

Torsional Strength of Converter Shafts and Elements

Strength and fatigue life of shafts and converters are evaluated on the basis of engine torque loadings and transient loads induced by severe vehicle operation. Accurate determination of transient values is entirely dependent upon modern dynamic recording equipment such as a four-channel, direct writing oscillograph.

A fatigue testing machine that applies input torque to the shaft is used to determine the strength and fatigue life of converter shafts.

The strength of die cast turbines is established by stress coat, strain gage measurements, and torsional fatigue tests. Because turbine loads are applied through a large number of blades, care must be exercised in securing the test part to the fixture to assure proper load distribution.

Overruning Clutch Testing—Static

Part of the geared converter arrangement of a Turboglide automatic transmission is an overrunning clutch. Its function is to permit a particular element to freewheel when it is no longer contributing to converter output. The Turboglide transmission uses three turbines, designated T_1, T_2 and T_3. The first two turbines are used during the low-speed and mid-speed ranges when the vehicle is being accelerated to cruising speed. Cruising speed uses only the T_3 turbine which is directly connected to the transmission output shaft. At this condition, overrunning clutches permit the T_1 and T_2 turbines to become free running in the converter oil stream. This action eliminates the drag and loss of efficiency that otherwise would occur. However, the overrunning clutches are called upon to provide high torque capacity in a small space. To evaluate the design of these clutches, a stroking fixture is used to determine fatigue life of overrunning clutch elements, such as the sprag type used in the Turboglide transmission, or the cam and roller clutches used under the stators of both the Turboglide and Powerglide transmissions (Fig. 8).

The operation is completely automatic, provides for repeated application of a predetermined torque, and provides sufficient rotation to establish new sprag-to-race contact points on each cycle.

Overrunning Clutch Testing—Dynamic

In the Turboglide automatic transmission Neutral-to-Drive shift, the T_1 sprag clutch must accept the sudden change from a high speed overrunning condition to a high torque lockup. The T_2 sprag clutch has a similar assignment when the change is made from road load to full throttle acceleration in the mid-speed range.

Machinery was developed to duplicate either of these conditions by providing: high speed rotation of the inner race; predetermined input torque to the outer race; means of grounding the inner race; and a measure of the reaction torque.

Testing is done on a single clutch, either the T_2 outer or T_1 inner sprag assembly. In either case the test piece is measured for strut angles, race diameters, and drag torque before entering the test machine.

The cycle begins with the outer race being driven through a reduction unit at 7 rpm. The inner race is driven in the same overrun direction. When it reaches 3,000 rpm, the driving motor is de-energized. A timer then engages a clutch (actually a Powerglide transmission clutch pack) between the inner race and a torque arm attached to a hydraulic cylinder. The rapid torque build-up on the sprags due to the abrupt lockup is limited to a specified value by a relief valve in the cylinder. Movement of the torque arm then trips a microswitch to disengage the clutch and the cycle is automatically repeated.

Converter Testing

In converter work, small changes in labyrinth seals, blade angles, and spoke designs exhibit non-linear effects on converter performance and efficiency. Evaluation of these effects necessitates a high degree of accuracy in the measurement of input and output speed and torque.

To make these measurements, a converter is mounted in a fixture designed to simulate the "in car" condition, and connected between two 250-hp dynamometers through rubber bushed propeller shafts. Direct current input and eddy current absorption dynamometers measure torque. The corresponding speeds are measured by digital counters. Frequent calibration of the dynamometers ensures the necessary accuracy.

In Turboglide transmission converter work, accurate measurement of the torque distribution between the three turbines throughout the operating range is essential to the evaluation of the effects on performance of small changes in design. This same basic equipment is used to make both steady state and dynamic measurements of these quantities.

Hydraulic Test Facilities

Equipment in a transmission laboratory must include the means for evaluat-

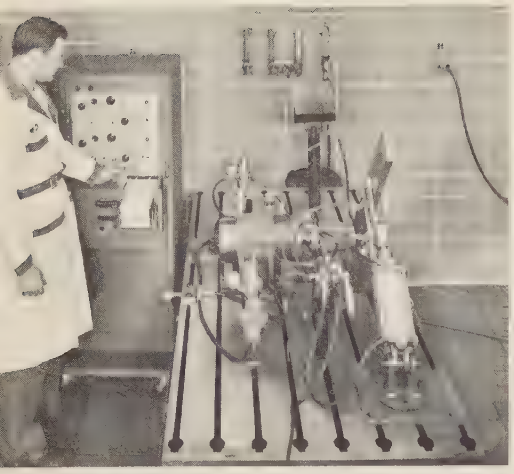

Fig. 8—In the overruning clutch static test machine pictured above, the load is applied by the air cylinder on the right through a torque arm where it is monitored by strain gages and recorded on the oscillograph. The apply load is limited by the known static breakaway capacity of two double wrap transmission bands attached to the outer race. The resulting rotation prevents brinnelling of the races due to repeated application in a fixed position.

ing pump and valve body performance, and parasitic losses.

Pumps are tested on a 15-hp dynamometer. The transmission is reworked to permit the normal pumping operation through suction and discharge passages. Oil pressure is controlled and flow is measured by a positive displacement meter.

A separate temperature controlled pumping unit supplies oil to an open sump beneath the transmission where a constant level and temperature are maintained.

Pump performance is gaged by measuring flow, pressure, input torque and speed, and vacuum at the suction side of the pump. Any restriction in either the suction or pressure passages which affects pump delivery or horsepower requirements is readily isolated.

This equipment also is used to measure parasitic loss. Measurements are made of input torque and speed. From this, the horsepower required to drive the transmission at various speeds is plotted.

Other equipment in the laboratory used for component parts testing includes a hydraulic flow bench which is used for valve body investigations. It provides two sources of pressure and oil flow and includes necessary measuring devices for trouble-shooting leaks, continuity of flow passages, regulation, shift valve calibration, and manual valve operation.

Another test fixture that has been of great value in automatic transmission testing is a spin rig. It permits variable speed input to the transmission and convenient measurement of associated pressures and input speed. This equipment is used for normal checkout on newly designed or revised transmissions and for trouble shooting on malfunctions.

Laboratory Data Supplements Road Tests

While final transmission performance must be evaluated on the basis of tests run in actual vehicles, it is possible to supplement these evaluations with quantitative data through the use of instruments and machines that record the torques, speeds, and hydraulic functions of a simulated test run.

Two such tests used by the laboratory are the abuse test and a programmed durability test.

The first consists of a series of manual shifts that records on a four-channel direct writing oscillograph the abuse capacity of the transmission. It shows the timing relationship of the clutch pressures and propeller shaft torques as well as clutch capacity and peak torque values.

The programmed durability test supplements the extensive testing of transmissions performed at the GM Proving Ground, and provides year around data without placing undue reliance on favorable weather conditions.

Information regarding engine speed and throttle angle, vehicle speed, time required to reach various car speeds, transmission range, and transmission oil temperatures and pressures, is collected from actual measurements on proving ground durability schedules. This information is fed to the programmer which then simulates transmission input loads by control of the engine throttle angle. Output loads and speeds are controlled by selected inertia discs and a dynamometer load. Transmission oil temperature and pressure safety interlocks are incorporated so that the programmer automatically stops cycling the transmission in case any of the physical quantities exceed the proper operating range. This saves expensive test pieces that have not failed during the test but would be destroyed or damaged by malfunction of other parts. The safety device also helps pinpoint the initial cause of the transmission failure[2].

Conclusion

The automatic transmission testing activities described illustrate how the personnel and facilities of an engineering laboratory contribute to the overall design of the vehicle. The aim of the Chevrolet Engineering Laboratory is to be able to perform any type of test or supply any data—short of road testing—that may be necessary in the development of a better product. As in most laboratories, much of the equipment consists of commercially available components; however, many other test devices are needed for special purposes and these must be developed and built in the laboratory. This special test equipment often requires considerable ingenuity on the part of the designer for time is not always available to develop a highly sophisticated machine. Lead time is significant in laboratory operations as well as in manufacturing operations.

To keep pace with new demands on the laboratory, engineers are constantly striving for better methods and improved testing equipment. For example, new hydraulic stroking machines have been developed and are being evaluated. These offer advantages of more power and versatility than mechanical stroking machines. A new rotary fatigue machine, which uses pneumatic loading, is an improvement over the former type using weights. Electronic programmers are being improved to provide automatic, repeatable cycling under a variety of test conditions. Other trends point to the increased use of computers, possible use of radioactive materials for wear and tracer studies, and wider application of electronic instrumentation. The vast potential for every type of automotive testing in the laboratory represents an invaluable aid in the development of soundly engineered automobiles and trucks.

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Some Comments on Trademarks and Copyright in the United States

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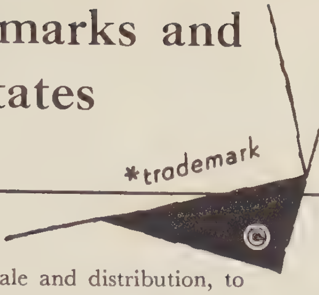

How the trademark and the copyright serve the holder

Attorneys responsible for the care of trademarks are continually confronted with inquiries or statements based on the concept that a trademark is somehow, or in some way, a kind of patent, or is protected as a patented invention. This erroneous concept may arise from the fact that trademarks used in interstate or foreign commerce may be registered in the U.S. Patent Office. Registration, however, does not create the trademark nor is it essential to its existence.

By definition a trademark is a name, symbol, figure, letter, form, or device adopted and *used* by a manufacturer or merchant to designate the goods which he manufactures or sells and to *distinguish* them from those manufactured or sold by another. The most important words of this definition, from the point of view of fully understanding the concept of a trademark, are the words *used* and *distinguish*. A trademark is created by use and is viable so long as it continues to be used as a trademark and continues to distinguish the source of the product*.

A patent is a statutory grant for a limited term of years which secures to an inventor the exclusive right to exploit his invention. Apart from the fact that both the trademark and the patent are species of industrial property, they have little else in common.

The Protection Accorded a Trademark

Many well-known trademarks are extremely valuable business assets, since they represent the goodwill created by customer satisfaction with the products on which they are used. What protection exists for this valuable property right? The owner of a trademark is entitled to prevent the use of any mark which so resembles his mark as to be *likely*, keeping in mind the goods on which the mark is used and all of the circumstances surrounding their sale and distribution, to cause confusion, or mistake, or to deceive purchasers. Otherwise stated, the test of infringement is whether a prospective purchaser is likely to believe that the goods bearing the new mark emanate from, or have the sponsorship of, or are connected with, the source of the old mark. If likelihood of such confusion can be proved, relief can be obtained. It is not necessary to prove actual confusion, although this often can be conclusive.

Adopting the Trademark

One who is about to use a trademark for the first time has an obligation not to use a mark the same as, or confusingly similar to, a mark already in use by another for similar or related goods or a mark that is universally known irrespective of the goods on which it is used. There are two reasons for this. First, infringement of another's mark is avoided and second, the mark chosen will truly distinguish the goods and thus be a good trademark.

A newly proposed mark, therefore, should be searched in the U.S. Patent Office, where many marks are registered, and in a private bureau which maintains a collection of marks that have been used but not registered. Even then there is a risk of anticipation, for all used marks are not available for search. The risk, however, is nothing more than a normal business risk.

Federal registration, while not essential to the existence or the protection of a trademark, can be quite helpful. A certificate of federal registration is evidence of the ownership of a trademark and of the exclusive right to use it. Having a certificate enables its owner to sue in the Federal Courts. It also is said to constitute notice of ownership of the mark throughout the United States, even though the mark is used in only a part of the country. Also, registration in the Patent Office creates a public record of ownership of a mark and guards against possible infringement.

Using the Trademark

The rights to the exclusive use of a trademark can be lost through nonuse, through misuse, or through express abandonment. If the mark is not used for such a period of time that it is no longer associated with a source, there can be an abandonment. This depends, however, upon the facts and circumstances surrounding the nonuse. If a continued intent to use can be shown, mere nonuse will not result in abandonment for there may have been factors which excuse the nonuse.

Loss of rights through misuse has been said to arise from facts which show that the trademark came to mean the name of a product rather than distinguishing the source of the product. This was the experience, for example, of "Cellophane" and "Aspirin."

It is important when using trademarks, and especially when referring to them in print, to use at least an initial capital letter. It also is a sound and useful rule, especially where new products are involved, to use the trademark as an adjective to qualify a generic or descriptive term that will identify the product. Otherwise, the trademark may become the name of the product and so lose its distinctiveness. Finally, generic words or words of mere description which are inherently incapable of distinguishing goods cannot become trademarks.

Other marks well known in business and industry which are similar to trademarks and are protected as trademarks are: *service marks*, used to identify and distinguish services; *certification marks*, used to indicate that the goods meet a certain standard of quality; and *collective marks*, used by members of an association to indicate their membership.

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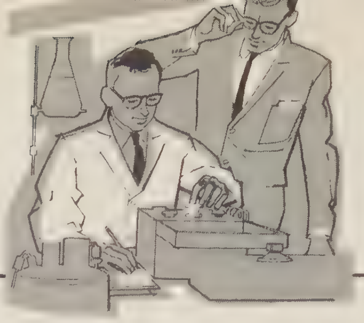
*In the United States trademark rights are based primarily on use while in some foreign countries, notably Germany and Argentina, they are based primarily on registration.

Notes About Inventions and Inventors



Contributed by
Patent Section
Detroit Office

The following is a general listing of patents granted in the names of General Motors employes during the period April 1, 1959 to June 30, 1959.

AC Spark Plug Division
Flint, Michigan

- **Argyle G. Lautzenheiser,** (*B.S.E.E., Tri-State College, 1940*) senior project engineer, inventor in patent 2,881,289 for a circuit control.
- **Homer R. Hastings,** (*B.S.E.E., Michigan State University, 1939*) staff engineer, and Clarence A. Haut, no longer with GM, inventors in patent 2,883,623 for electromagnetic indicating instruments.
- **Fortunato Barberis,** (*M.M.E., 1922, and Ph.D. in Aero. E., 1923, Royal Polytechnical, Torino, Italy*) project engineer, inventor in patent 2,885,859 for an injector igniter plug.
- **John D. McMichael,** (*Michigan State University*) product engineer, inventor in patent 2,886,130 for a cleaner silencer assembly.
- **Gustav F. Rademacher,** (*B.S., Michigan State University, 1941*) project engineer, inventor in patent 2,888,508 for a thermocouple.
- **Lucian B. Smith,** (*B.E.E., The Ohio State University, 1923*) executive engineer, inventor in patent 2,889,782 for a fuel pump with magnet.

Allison Division
Indianapolis, Indiana

- **Harry C. Karcher,** (*B.S.Aero.E., Massachusetts Institute of Technology, 1925*) chief, Field Service Department, inventor in patent 2,880,573 for an afterburner fuel injection system.
- **Carl L. Nigh,** (*B.M.E., General Motors Institute, 1953*) senior project engineer, inventor in patent 2,881,033 for a bearing assembly.
- **Harry C. Karcher*,** and Otto T. Kreuser, retired, inventors in patent

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(*Continued from page 31*)

The Copyright Protects Against Copying

There are two kinds of copyright—statutory and common law.

Common law copyright is sometimes defined as the right to first publication, for on first publication, the common law copyright vanishes and the work is dedicated to the public, that is—it may be copied without sanction, unless statutory copyright is invoked by publishing with the required notice of copyright. Statutory copyright, as in the case of a patent, is limited to a definite term. The copyright term is 28 years with a right of renewal for a further term of 28 years.

While there is little or no formality involved in the adoption and use of a trademark, statutory copyright, on the other hand, is created largely through a formality; namely, the use of the proper notice in the proper place when first publishing a work in which copyright is sought.

For copyright classification purposes, "books" may vary from a single page and leaflet to a thousand page volume. For such material, as well as for all printed literary, musical, and dramatic works, the copyright notice must include either the symbol ©, the word "Copyright," or its abbreviation "Copr.," as well as the name of the copyright proprietor and the year in which the work was published. Use of the symbol © may result in securing copyright in countries which are members of the Universal Copyright Convention. In the case of books, the notice must be placed on the title page or on the page immediately following the title page. For other types of work, such as works of art, the notice may simply be the symbol © accompanied by the initials of the proprietor, provided the name of the proprietor appears elsewhere on the work in an accessible place. Any deviation from the requirements as to the copyright notice, which are statutory and strictly construed, will raise a serious doubt as to the validity of the copyright. For this reason, the requirements of each class of work on which copyright is sought should be carefully checked.

After the work has been published with notice, the statute requires that copies be deposited in the Library of Congress. Following deposit and acceptance, a certificate is issued. The certificate of copyright is important since it is a prerequisite to suit although it is not a prerequisite to a valid claim of copyright.

What protection is afforded by the law of copyright? Simply stated and understood literally, the protection is against copying. Thus, if two authors, working independently, should, by sheer coincidence, write a book on the same subject with the same arrangement of words so that both works were identical in all respects, each could acquire a copyright in his work for there was no copying. The likelihood of such coincidence, however, is so remote that word for word duplication of two works would, as a practical matter, probably be regarded as an infringement of one or the other work. But even so, it would be necessary to show access to, and copying of, the prior work, although the burden of proving copying is reduced considerably where word for word duplication is involved.

Paraphrasing or abridgment of copyrighted works can be an infringement if substantial copying can be shown. Knowledge and ideas cannot be protected by copyright. What is protected are the words or drawing expressing or depicting the knowledge or idea.

2,882,679 for an augmenter type afterburner for jet propelled aircraft.

- **Robert M. Tuck,** (*B.M.E., General Motors Institute,1947*) chief development engineer, inventor in patent 2,884,806 for hydraulic control systems for automotive transmissions.

- **Eugene G. Bevers,** (*B.S.M.E., University of Wisconsin, 1945*) group senior project engineer, and **Frederick O. Zimmer,** (*commercial engineering degree, University of Cincinnati, 1940*) senior project engineer, inventors in patent 2,884,997 for a gas turbine fuel system including a starting accumulator.

- **Arthur R. Mauck,** (*B.M.E., General Motors Institute, 1951, and American University, Washington, D.C., 1941*) in charge of special projects group, and John M. Zorad, no longer with GM, inventors in patent 2,886,133 for an oil mist turbine lubrication.

- **Earl J. Clark,** (*B.S.M.E., Purdue University, 1941*) head, engineering section, Bearing Department, inventor in patent 2,890,086 for a bearing assembly.

- **Wilgus S. Broffitt,** (*B.S.M.E., University of Kentucky, 1938*) head, Design Group, inventor in patent 2,891,382 for a liquid cooled turbine.

- **Harry F. Pesel,** (*B.S. in radio engineering, Indiana Technical College, 1949*) supervisor, dynamics, inventor in patent 2,891,746 for a resilient accessory mount.

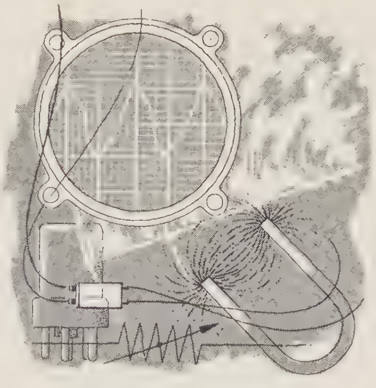
- **Dean K. Hanink,** (*B.S.Met.E., University of Michigan, 1942*) chief metallurgist, inventor in patent 2,881,750 for a valve.

Aeroproducts Operations Allison Division Vandalia, Ohio

- **Richard A. Hirsch,** (*University of Dayton and Sinclair College*) section head—Electra propellers; James R. Mansfield, no longer with GM; and **Harry N. Nelson,** (*Miami University and Denison University*) designer, inventors in patent 2,882,975 for a propeller mechanical pitch lock and low pitch stop assembly.

- **Virgil Battenberg,** (*M.E., University of Dayton, 1958*) senior project engineer; **Dale W. Miller,** (*B.S., Wittenberg College 1934*) assistant chief engineer; Harold Detamore and Richard E. Moore, not with GM, inventors in patent 2,883,178 for a centrifugally responsive governor valve assembly.

- **Howard M. Geyer,** (*B.S.I.E., University of Alabama, 1940*) chief research engineer, and **James W. Light,** (*Miami University and The Ohio State University*) experimental engineer, inventors in patents 2,886,008 and 2,891,380 for a locking actuator and valve mechanism therefor and a dual drive actuator and control means therefor, respectively.



- **Clifford B. Wright,** (*A.B., Wittenberg College, 1938*) chief engineer; **Thomas Barish,** consultant; Charles F. Irwin, not with GM; and Russel E. Line, no longer with GM, inventors in patent 2,886,112 for a rotatable seal for cowlings.

- **Dale W. Miller*,** and Sylvan G. Hendrix, not with GM, inventors in patent 2,887,164 for a propeller control system.

- **Richard A. Hirsch*; Edward H. McDonald,** (*B.S.M.E., University of Dayton, 1950*) project engineer; and Sylvan G. Hendrix*, inventors in patent 2,888,992 for a propeller mechanical low pitch stop.

- **Clyde A. Ditmer,** (*University of Cincinnati*) checker, and **Richard A. Hirsch*,** inventors in patent 2,891,627 for a variable pitch propeller and oil reservoir therefor.

Buick Motor Division Flint, Michigan

- **Frank R. L. Daley, Jr.,** (*B.S. in physical and biological sciences, University of Massachusetts, 1940*) staff engineer, inventor in patent 2,880,744 for a housing vent.

- **Leonard M. Morrish,** (*Michigan State University*) staff engineer, and **Lloyd E. Muller,** (*B.S.M.E., University of Kansas, 1929*) director, Experimental Engineering, inventors in patent 2,881,852 for an exhaust muffler means.

- **Oliver K. Kelley,** (*B.S., Chicago Technical College, 1925 and Massachusetts Institute of Technology*) chief engineer, inventor in patents 2,882,684 for a hydraulic torque converter; 2,882,751 for a transmission; 2,884,813 for a plural step transmission; and 2,889,717 for automatic plural transmissions.

- **Henry W. Boylan,** (*Wayne State University, 1929*) staff engineer; **Harry C. Doane,** now assistant to the vice president in charge of GM Engineering Staff; and **Lloyd E. Muller*,** inventors in patent 2,883,161 for systems for modifying heat content of air introduced into vehicles.

- **Leonard M. Morrish*,** inventor in patent 2,888,001 for induction heating means.

- **Henry W. Boylan*,** inventor in patent 2,891,388 for vehicle air conditioning apparatus.

- **Joseph D. Turlay,** (*B.S.M.E., Oregon State College, 1928*) director, Power Plant Activities, inventor in patent 2,891,532 for a fuel injection system.

- **Archie D. McDuffie,** (*General Motors Institute, 1934*) staff engineer, inventor in patents 2,882,830 and 2,891,529 for a distortionable chamber pump and a charge forming means, respectively.

Cadillac Motor Car Division Detroit, Michigan

- **Bruce Edsall,** (*B.S.M.E., Wayne State University, 1942*) staff engineer, inventor in patent 2,882,757 for a self-energizing assistor for torque-establishing devices.

- **Hugo H. Wendela,** (*B.S.Aero.E., Wayne State University, 1936*) assistant staff engineer, inventor in patent 2,886,270 for a fastening device.

***Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.**

- **Daniel M. Adams,** (*Detroit Institute of Technology and University of Michigan*) staff engineer, and **Louis P. Garvey,** (*B.M.E., University of Detroit, 1940*) assistant engineer in charge, Product Engineering Activity, Design and Drafting Department, Fisher Body Division, inventors in patent 2,890,299 for a selector and indicator device.

Central Foundry Division
Fabricast Plant
Bedford, Indiana

- **Harold L. Benham,** (*B.S. in physics, Indiana University, 1951*) development engineer, inventor in patents 2,881,490 for a method of forming an aluminum casting with a bronze insert and 2,890,915 for forming an aluminum casting with a bronze insert.

Chevrolet Motor Division
Detroit, Michigan

- **Adelbert E. Kolbe,** (*University of Michigan*) assistant staff engineer, inventor in patent 2,882,875 for an inlet manifold.

- **Zora Arkus-Duntov,** (*M.E., Institute of Charlottenburg, Berlin, Germany, 1934*) staff engineer, inventor in patent 2,882,883 for a fuel induction system.

- **William S. Wolfram,** (*B.S.M.E., University of Michigan, 1933*) assistant staff engineer; Maurice Olley, retired; and Frederick C. Walther, no longer with GM, inventors in patent 2,883,232 for vehicle construction.

- **Charles M. Rubly,** assistant staff engineer, inventor in patent 2,885,035 for a brake mechanism.

- **Howard H. Kehrl,** (*B.S.M.E., Illinois Institute of Technology, 1944*) staff engineer, inventor in patent 2,885,047 for a clutch assembly.

- **Gerald F. Hause,** (*B.S.E.E., University of Michigan, 1950*) senior experimental engineer, GM Proving Ground, inventor in patent 2,885,458 for a combination ignition coil and ignition distributor.

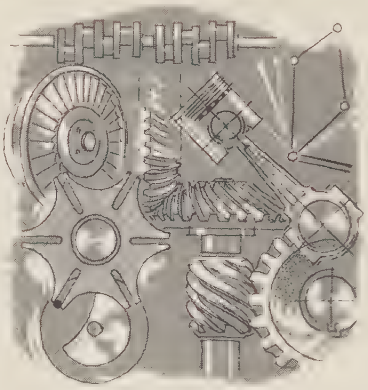
- **William S. Wolfram*,** inventor in patent 2,888,270 for a stabilizer controlled leveling valve for air suspended vehicle.

- **Ellis J. Premo,** (*Chrysler Institute*) executive assistant chief engineer, inventor in patent 2,888,274 for automotive fender air duct structures.

- **Frank J. Winchell,** (*Purdue University*) staff engineer, inventor in patent 2,891,828 for a transmission.

- **Robert Schilling,** (*M.E. degree, Technical University, Munich, Germany, 1922*) director, Research and Development Department, inventor in patent 2,890,895 for rear spring suspension for vehicles.

- **Alva Lloyd Nedley,** (*A.B. in physics, Washington and Jefferson University, 1947; B.S.M.E., Carnegie Institute of Technology, 1949; and M.S.M.E., Lehigh University, 1951*) senior experimental engineer, inventor in patent 2,882,881 for a choke flow intake silencer and method.



Cleveland Diesel Engine Division
Cleveland, Ohio

- **Paul M. Stivender,** (*University of Wisconsin Extension*) special projects engineer, inventor in patent 2,882,687 for closed circuit turbines.

- **Morris W. Carlson,** chief mechanical engineer, inventor in patent 2,885,919 for a tool.

Delco Appliance Division
Rochester, New York

- **Walter D. Harrison,** project engineer, and John B. Dyer, deceased, inventors in patent 2,880,621 for mechanical movement.

- **Donald W. Laviana,** (*B.S.M.E., Yale University, 1944*) project engineer, inventor in patent 2,882,370 for a thermostat.

- **Carl J. Finsterwalder,** (*B.S.E.E., Clarkson College, 1928*) design engineer; **Milton E. Simmons,** (*B.S.E.E., Rensselaer Polytechnic Institute, 1950*) project engineer; and **Frank J. Terkoski,** (*B.S.E.E., Pennsylvania State University, 1950*) project engineer, inventors in patent 2,883,183 for vehicle window actuators.

- **Cloyd L. Betzer,** (*M.E., Cornell University, 1939*) heating engineer, inventor in patent 2,886,295 for a heat exchanger for warm air furnaces.

Delco Products Division
Dayton, Ohio

- **James L. Hancock,** (*B.S.Ch., Butler University, 1950*) project engineer, inventor in patent 2,881,368 for a vent cap for electrolytic condenser.

- **George W. Jackson,** (*B.S.M.E., Purdue University, 1937*) assistant chief engineer in charge of automotive products, inventor in patents 2,887,324 and 2,888,273 for a fluid suspension control mechanism and a control for fluid suspension system, respectively.

- **William P. Stewart, Jr.,** (*M.E., Virginia Polytechnic Institute*) now senior project engineer, Chevrolet Motor Division, inventor in patent 2,891,577 for a control device.

Delco Radio Division
Kokomo, Indiana

- **Max J. Manahan,** (*B.S.E.E., Milwaukee School of Engineering, 1922*) staff engineer, inventor in patent 2,882,391 for an electric radio tuner.

- **James H. Guyton,** (*B.S.E.E., 1934 and M.S.E.E., 1935, Washington University*) chief engineer—radio, inventor in patents 2,890,274 and 2,891,197 for signal seeking tuners for television and a photoelectric transistor switch control, respectively.

- **Harold W. Coppock,** senior layout draftsman, inventor in patent 2,892,908 for an electric switch.

Detroit Diesel Engine Division
Detroit, Michigan

- **Henry V. Shaw,** (*B.S.E.E., Pennsylvania State University, 1937*) senior engineer, inventor in patent 2,881,376 for an induction motor control system.

- **Charles H. Frick,** (*B.S., Iowa State College, 1934*) senior project engineer, inventor in patent 2,884,807 for a power plant control mechanism.

- **Stephen A. Larkin,** senior special tester, and **Norman H. Ledwan,** (*Lawrence Institute of Technology, Wayne State University and University of Michigan*) senior project engineer, inventors in patent 2,890,069 for a rotary seal.

- **John J. May,** (*B.S.Aero.E., New York University, 1930*) forward design and development engineer, and **Ray C. Ulrey,** (*B.S.M.E., Purdue University, 1936*) senior designer, inventors in patent 2,890,657 for a unit injector pump with pilot injection.

- **Charles H. Frick*,** and **Grove H. Shephard,** senior checker, inventors in patent 2,891,526 for an engine control mechanism.

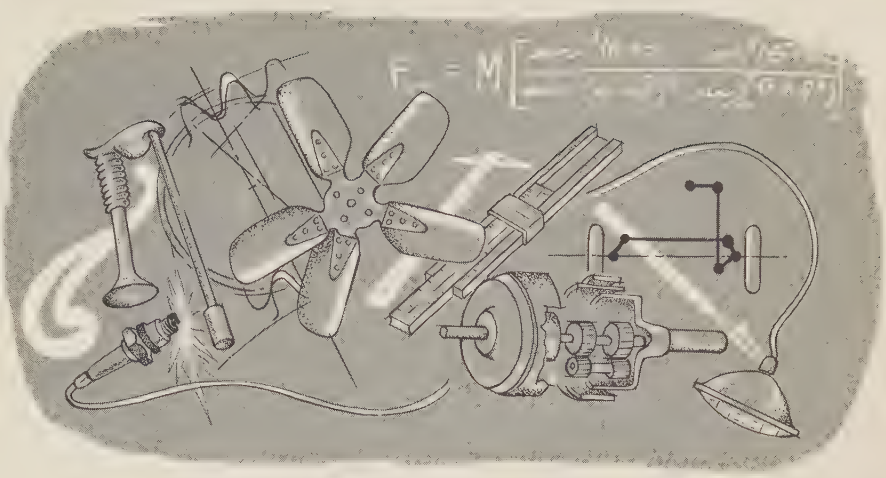
Detroit Transmission Division
Ypsilanti, Michigan

- **Earl L. Egbert,** (*B.M.E., University of Akron, 1948*) senior project engineer, inventor in patent 2,890,661 for a hydraulic coupling.

Diesel Equipment Division
Grand Rapids, Michigan

- **William A. Fletcher,** (*General Motors Institute, 1930*) director, Manufacturing Facilities and Services, inventor in patent 2,888,272 for a suspension system.

Electro-Motive Division
La Grange, Illinois



- **Carl R. Sakraida,** senior designer, and **Robert H. Wellman,** (*B.S.M.E., Northwestern University*) mechanical design engineer, inventors in patent 2,880,709 for free piston construction.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

- **William F. Holin,** (*M.E., Konstanz, Germany*) senior project engineer, inventor in patent 2,885,034 for brake rigging for railway vehicle truck.

- **Joseph M. Burke,** senior project engineer, inventor in patent 2,885,095 for a coupler operating device.

GM Engineering Staff
Detroit, Michigan

- **John B. Clark, Jr.,** (*M.S.M.E., University of Michigan, 1951*) project engineer, inventor in patent 2,880,714 for a fuel injection system.

- **Gilbert K. Hause,** engineer in charge, Transmission Development Group, **Clifford C. Wrigley,** (*B.S.M.E., University of Colorado, 1936 and Yale University*) assistant engineer in charge, Transmission Development Group; and **Oliver K. Kelley,** now chief engineer, Buick Motor Division, inventors in patent 2,882,545 for windshield cleaning apparatus.

- **John T. Marvin,** (*B.S.Chem.E., Case Institute of Technology, 1934, Western Reserve University and Franklin College*) patent attorney, Patent Section, Dayton, Ohio, office, inventor in patent 2,882,700 for an ice block ejecting arrangement.

- **William H. Kolbe,** (*B.S.M.E., University of Michigan, 1950*) senior project engineer, and John Dolza, no longer with GM, inventors in patent 2,886,057 for a fuel injection filter system.

- **Gilbert K. Hause*,** inventor in patent 2,886,950 for a quick take-up master cylinder, and patent 2,890,769 for a brake actuator.

- **L. Glenn Hogsten,** (*General Motors Institute*) section engineer, inventor in patent 2,888,269 for a vehicle frame.

- **Douglas T. Lewis,** (*B.M.E., Syracuse University, 1949*) section engineer, inventor in patent 2,890,581 for a transmission lock.

- **Stanley H. Mick,** (*B.M.E., General Motors Institute, 1955*) project engineer, and John Dolza*, inventors in patent 2,891,528 for an idle air valve.

- **Dale B. McCormick,** (*University of Michigan*) section engineer, inventor in patent 2,891,822 for a track closure.

Fisher Body Division
Detroit, Michigan

- **James D. Leslie,** (*B.M.E., University of Detroit, 1939*) engineer in charge, Mechanical Department; **Clyde H. Schamel,** (*B.S.E.E., University of Notre Dame, 1927*) engineer in charge, Central Experimental and Development Department; and **Harold E. Van Voorhees,** (*B.S.M.E., Purdue University, 1915*) senior design engineer, inventors in patent 2,881,019 for a door latch for a pillarless automobile.

- **Robert M. Fox,** (*B.M.E., General Motors Institute, 1950*) senior project engineer, and **Russell A. Grout,** senior layout man, inventors in patent 2,886,364 for a rear compartment lock striker.

- **James D. Leslie*,** and **Henry J. Wubbe,** layout draftsman, inventors in patent 2,887,866 for door latch operating apparatus.

- **Edward R. Kalis,** (*Ford Trade School, 1927*) general foreman of plastic forms and Keller machine setup, inventor in patent 2,887,971 for a composite die.

- **Louis P. Garvey,** (*B.M.E., University of Detroit, 1940*) assistant engineer in charge, Product Engineering Activity; **John G. Haviland,** (*B.S.E., 1937, and M.S.Ch.E., 1939, University of Michigan*) senior project engineer; and Hugh R. Brand, no longer with GM, inventors in patent 2,892,657 for a glass run channel.

Frigidaire Division
Dayton, Ohio

- **Jesse L. Evans,** (*B.S.M.E., University of Dayton, 1943*) senior project engineer, and **Kenneth O. Sisson,** (*B.S.M.E., South Dakota State College, 1936*) senior project engineer, inventors in patent 2,880,479 for a trim strip assembly.

- **James W. Jacobs,** (*B.S.M.E., University of Dayton, 1954*) manager, research and future products engineering, inventor in patent 2,881,597 for two speed drive and control means for refrigerating apparatus; 2,888,808 for refrigerating apparatus; and 2,892,319 for refrigerating apparatus.

- **Byron L. Brucken,** (*B.S., University of Dayton, 1956*) senior project engineer, inventor in patents 2,881,609 and 2,882,706 for a combined clothes washing machine and dryer and a tympanic jet washer, respectively.

- **Kenneth O. Sisson*,** inventor in patent 2,882,360 for a domestic appliance.

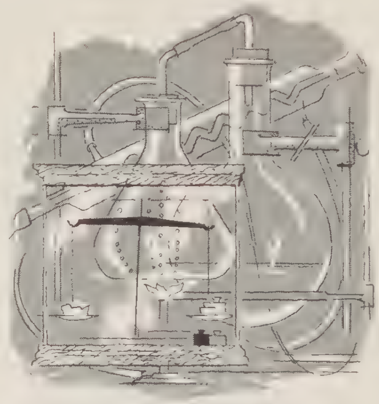
- **George B. Long,** (*B.S.E.E., Purdue University, 1937*) supervisor of major product line, inventor in patent 2,882,379 for a domestic appliance.

- **Richard E. Gould,** (*B.S.M.E., 1923 and M.S.M.E., 1927, University of Illinois*) chief engineer, inventor in patent 2,884,768 for automobile refrigerating apparatus.

- **Keith K. Kesling,** (*University of Dayton and Dayton Art Institute*) project and design engineer, inventor in both patents 2,885,253 and 2,888,544 for a domestic appliance.

- **Ronal H. Whyte,** (*Sinclair College, 1935*) senior engineer, and **Nelson J. Pansing,** (*Sinclair College*) special tester, inventors in patent 2,886,901 for a seal for rotary drum drier.

- **Richard S. Gaugler,** (*B.S.Ch.E., Purdue University, 1922*) supervisor of major product line, inventor in patent 2,887,346 for a shaft bearing.



- **Wendell M. Thomas,** (*M.E., University of Cincinnati, 1950*) senior engineer, inventor in patent 2,887,852 for an ice maker.

- **Robert D. Bremer,** (*B.S.E.E., Purdue University, 1934*) senior project engineer, inventor in patent 2,888,656 for a sheathed tubular electrical heater seal.

- **Carl M. Schell,** (*Wittenberg College and University of Chicago*) general supervisor of drafting, inventor in patent 2,889,787 for a door opener.

- **Jesse L. Evans*,** inventor in patent 2,889,825 for a domestic appliance.

GMC Truck and Coach Division
Pontiac, Michigan

- **William T. Menewisch,** (*Drexel Institute*) patents, standards, and regulations engineer, inventor in patent 2,881,799 for a two way height control overrule for air suspended vehicle.

- **Wallace M. Kennedy,** (*B.A. in science, University of Toronto, 1923*) engineer, and Walter S. Fisher, retired, inventors in patent 2,886,022 for a carburetor control system.

- **Lewis R. Hetzler,** (*B.S.E.E., University of Michigan, 1941*) now director, Applied Science Department, Delco-Remy Division, inventor in patent 2,886,765 for a magnetic amplifier voltage regulator.

- **Hans O. Schjolin,** (*B.S. degree, Karlstad College, Sweden, 1920 and Polytechnical Institute, Mittweida, Germany, 1923*) advance design engineer, inventor in patent 2,889,691 for refrigerating apparatus.

- **Millis V. Parshall,** (*B.S.M.E., University of Michigan, 1918*) project engineer, and **Hans O. Schjolin*,** inventors in patent 2,889,718 for a V-drive transmission with hydraulic clutch.

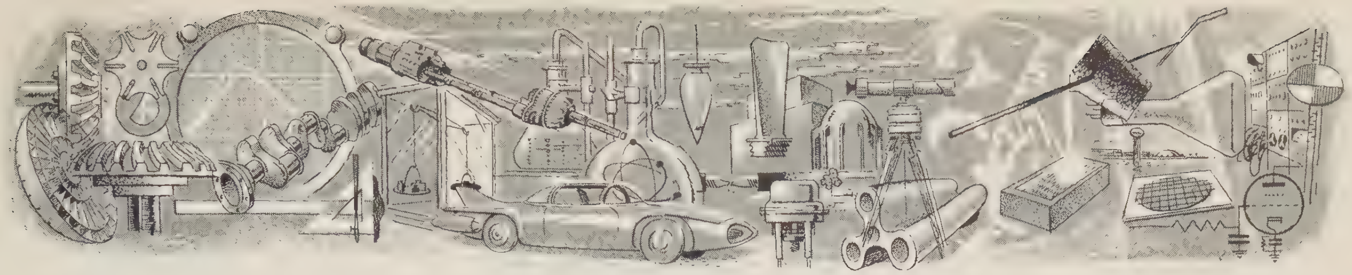
Guide Lamp Division
Anderson, Indiana

- **Franklin H. Meek,** (*International Correspondence School*) machine designer; **Sylvanus Meyer,** master mechanic; **Harold E. Todd,** (*B.S.E.E., Purdue University, 1940*) senior project engineer; **Glenn E. Wanttaja,** (*B.S.E.E., Michigan College of Mining and Technology, 1950 and M.S.E.E., Wayne State University, 1956*) now senior project engineer, AC Spark Plug Division, Milwaukee, Wisconsin, plant; and Raymond A. Gaither, no longer with GM, inventors in patent 2,880,557 for headlamp pre-aiming apparatus.

- **Eugene G. Matkins,** (*B.M.E., General Motors Institute, 1952*) project engineer, inventor in patent 2,888,611 for a light controlled headlight on-off switch.

- **Eugene G. Matkins*,** and **Kenneth R. Skinner,** (*B.S. in radio engineering, Tri-State College, 1955*) project engineer, inventors in patent 2,890,386 for an automatic headlamp control system.

- **George W. Onksen,** (*B.I.E., General Motors Institute, 1956 and Purdue University*) staff engineer, and Eugene S. Reynolds, no longer with GM, inventors in patent 2,890,627 for a method for making lens mold.



Harrison Radiator Division
Lockport, New York

- **Hugh J. Clifford,** (*B.S.M.E., University of Buffalo, 1950 and General Motors Institute, 1937*) senior project engineer, and **Adolph Schwarz,** senior product designer, inventors in patent 2,881,616 for thermostatic power elements.

Hyatt Bearings Division
Harrison, New Jersey

- **Walter A. Butkus,** (*Newark College of Engineering*) designer, inventor in patent 2,891,827 for a flexible seal.

Inland Manufacturing Division
Dayton, Ohio

- **Cletus L. Moorman,** (*University of Dayton*) project engineer, and Elwood F. Riesing, deceased, inventors in patent 2,883,224 for a fluid seal.

- **Edward P. Harris,** (*M.E., Cornell University, 1931*) project engineer, and **James R. Wall,** (*B.Ch.E., University of Dayton, 1937 and M.Ch.E., Cornell University, 1939*) supervisor, Advanced Development Laboratory, inventors in patents 2,884,668 and 2,884,957 for a plural coated spongy sealing strip and a flexible tubing, respectively.

- **Herman S. Ralph,** tool engineer; **Urban P. Nellis,** methods engineer; and William L. Pearson, no longer with GM, inventors in patent 2,886,213 for fluid flow apparatus.

- **Arthur J. Frei,** senior project engineer, inventor in patent 2,886,958 for a freezing device.

- **Guy R. Overman,** (*General Motors Institute, 1935*) chief experimental engineer, inventor in patent 2,892,359 for a steering wheel.

Oldsmobile Division
Lansing, Michigan

- **Kenneth E. Faiver,** (*B.S.E.E., Notre Dame University, 1924 and Ph.D., Rensselaer Polytechnic Institute, 1927*) senior project engineer, inventor in both patents 2,882,068 and 2,882,069 for an air suspension control system.

- **Robert D. Tower,** (*B.M.E., General Motors Institute, 1949*) assistant body design engineer, inventor in patent 2,885,041 for a fastening device.

- **Gilbert Burrell,** (*B.S.E.E., Michigan State University, 1928*) motor engineer, inventor in patent 2,886,021 for a carbureting system.

- **Richard N. Sussex,** (*General Motors Institute, 1954*) detail project engineer, inventor in patent 2,888,702 for a windshield wiper blade assembly.

- **Ralph W. Perkins,** (*B.S.M.E., Purdue University, 1937*) assistant chassis engineer, inventor in patent 2,890,062 for an independent wheel suspension with caster and camber adjustment means.

Pontiac Motor Division
Pontiac, Michigan

- **John H. Keller,** group leader, design or drafting, inventor in patent 2,882,744 for a clutch operating mechansim.

- **John F. Verkerke,** (*B.S.M.E., University of Michigan, 1944*) senior project engineer, inventor in patent 2,883,168 for a fuel injection system venting device.

***Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.**

- **Mark H. Frank,** (*B.S.M.E., Michigan State University, 1927*) motor engineer, inventor in patent 2,887,900 for an eccentric bushing.

Rochester Products Division
Rochester, New York

- **Clarence R. Lunn,** supervisor, Michigan area sales engineers, inventor in patents 2,881,746 and 2,890,871 for a carbureting system and an anti-icing carburetor, respectively.

- **Donald D. Stoltman,** (*B.S.M.E., Rensselaer Polytechnic Institute, 1947 and M.S. in automotive engineering, Cornell University, 1948*) senior project engineer, inventor in patent 2,883,112 for air bleed control.

- **Donald G. Dening,** (*A.A.S. in M.E., Rochester Institute of Technology, 1948*) project engineer, and **Homer V. Krautwurst,** (*B.S.M.E., University of Rochester, 1941*) senior project engineer, inventors in patent 2,883,510 for a cigar lighter assembly.

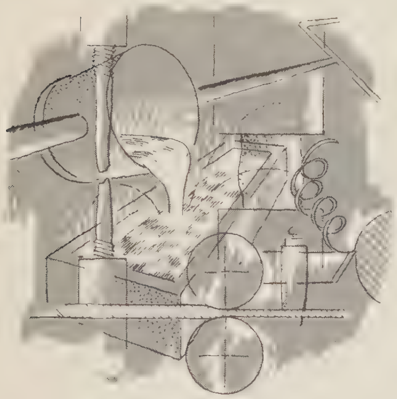
- **Bernard E. Frank,** (*C.E., Ecole Speciale D'Inginieur Technicien, Charleroi, Belgium, 1939*) senior engineer; **Marlin E. Hazen,** (*B.Aero.E., Rensselaer Polytechnic Institute, 1950*) process engineer; and **Fay H. Stroud,** (*Detroit College of Applied Science and Rochester Institute of Technology*) senior engineer, inventors in patent 2,885,914 for a small hole drilling machine.

- **Ronald C. Groves,** (*B.E.E., 1936 and B.M.E., 1937, Lawrence Institute of Technology*) staff engineer, inventor in patent 2,891,531 for a fuel injection system.

GM Research Laboratories
Detroit, Michigan

- **Robert F. Thomson,** (*B.S.M.E., 1937; M.S.M.E., 1940; and Ph.D., 1941, University of Michigan*) head, Metallurgical Engineering Department, and **Eric W. Weinman,** (*B.S.Chem.E., 1938; M.S.Met. E., 1958; Wayne State University*) senior metallurgist, inventors in patent 2,882,190 for a method of forming a sintered powdered metal piston ring; 2,884,687 for a wear-resistant sintered powdered metal; and 2,887,765 for a sintered powdered copper base bearing.

• **John L. Harned,** (*B.E.E., University of Detroit, 1952 and M.S.M.E., Wayne State University, 1957*) senior research engineer; **Roy F. Knudsen,** (*B.S.E.E., Swarthmore College, 1949*) now assistant engineer in charge, Test Facilities, Instrumentation Section, GM Engineering Staff; and **Francis M. Ward,** (*University of Detroit*) applications group leader, inventors in patent 2,882,721 for a simulated inertia weight system.



• **William A. Turunen,** (*B.S.M.E., Michigan College of Mining and Technology, 1939 and M.S. degree, Columbia University, 1946*) head, Engineering Development Department, and Patrick W. O'Connell, deceased, inventors in patent 2,883,152 for an evaporative cooled turbine.

• **Robert F. Thomson*; Dean K. Hanink,** chief metallurgist, Allison Division; and Albert A. Shoudy, Jr., Atomic Power Development Associates, inventors in patent 2,885,304 for a method of aluminum coating.

• **James C. Holzwarth,** (*B.S.M.E., 1945 and M.S.M.E., 1948, Purdue University*) supervisor, Metallurgical Engineering, and **Robert F. Thomson*,** inventors in patent 2,883,280 for a ferrous base alloy.

• **Eugene A. Hanysz,** (*B.S.E.E., 1945 and M.S.E.E., 1948, University of Michigan*) supervisor of instrument engineering, Physics Department, inventor in patent 2,885,887 for ultrasonic testing.

• **William C. Bubniak,** (*B.S.M.E., Lawrence Institute of Technology, 1949*) senior design engineer, and **Paul T. Vickers,** (*B.M.E., General Motors Institute, 1948*) supervisor, Heat Transfer Section, Engineering Development Department, inventors in patent 2,888,248 for a rotary regenerator seal.

• **Eugene A. Hanysz*,** and **Norman W. Schubring,** (*B.S.E.E., 1952 and M.S.E.E., 1959, Wayne State University*) senior research engineer, inventors in patent 2,889,705 for a material thickness and deflect testing device.

• **John S. Collman,** (*B.S., Naval Architecture and Marine Engineering, University of Michigan, 1940*) assistant head, Engineering Department; **William A. Turunen*;** and **Paul T. Vickers*,** inventors in patent 2,890,024 for a regenerative heat exchanger.

Saginaw Steering Gear Division
Saginaw, Michigan

• **William B. Thompson,** (*B.M.E., General Motors Institute, 1950*) on leave of absence, inventor in patent 2,882,867 for a closed center valve with zero leak feature.

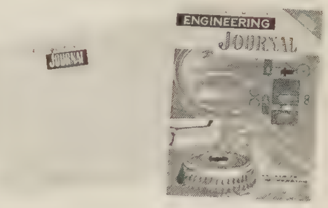
• **David A. Galonska,** staff engineer, inventor in patents 2,890,594 and 2,891,823 for a helical spline assembly, and a ball bearing spline, respectively.

GM Styling Staff
Detroit, Michigan

• **Frank P. Biondo,** (*University of Detroit*) assistant chief engineer, inventor in patent 2,883,234 for a vehicle dash compartment.

• **Robert F. McLean,** (*B.S.M.E., 1943 and professional degree in industrial design, 1948, California Institute of Technology*) executive in charge, Automotive Research Design, and **Edward G. Podolan,** (*Lawrence Institute of Technology*) senior project engineer, inventors in patent 2,890,908 for a power operated luggage compartment for motor vehicles.

About Distribution of the JOURNAL to Educators



The General Motors Engineering Journal is a publication designed primarily for use as supplementary information by college and university educators in the fields of engineering, the physical sciences, mathematics, and industrial design. It is supplied to these educators on a request basis at no charge.

At some institutions there may be educators in the above categories who are not aware that they can receive the Journal on a regular basis. For example, some of these persons might be new members of the faculty. Educators presently on the mailing list of the journal are invited to inform their colleagues of the availability of this publication.

When desired, educators may receive multiple copies of the Journal on a regular basis or for special uses. Copies of most of the back numbers may be obtained on request. The final issue in each Volume of the Journal (designated by calendar year beginning with 1954) contains an index by subject, title of paper, or author.

As announced in the July-August-September 1959 issue, reprints of typical problems in engineering have been arranged in booklet form. A separate booklet contains reprints of the solutions. Both of these items also are available to educators on request at no charge.

Comments from educators always are welcome. In the past, educators' suggestions and advice on subject matter and method of presentation have been helpful in guiding GM scientists and engineers in their efforts of preparing papers for best use in connection with the study of fundamentals.

A Typical General Motors Institute Classroom Problem:

Determine the Entropy Values for Low Pressure, Superheated Water Vapor

Faculty Member in Charge:
ELWOOD K. HARRIS

G.M.I. Cooperative Student:
ROBERT D. FLETCHER
Electro-Motive Division

Information concerning data on the properties of low pressure, superheated water vapor is not generally available. Without such data, problems dealing with exhaust products, water injection, turbocharging, and high altitude operation cannot be investigated completely. The problem presented here is to expand the temperature-entropy diagram to provide the required information on superheated water vapor at low pressures and high temperatures.

Apply thermodynamic principles to extend a temperature-entropy plot

A STUDY of the effect ambient temperature and pressure conditions have on internal combustion engine performance is somewhat hampered due to the lack of sufficient data presented by a temperature-entropy (T-S) diagram in the low pressure, superheat region. Most intake and exhaust conditions found in an internal combustion engine cover a temperature range of from 0° F to 1,200° F and include pressures as low as 1/4-in. mercury (0.1478 psi).

The existing T-S data terminate at an entropy of 2.25 Btu per lb °F (Fig. 1). A pressure of 1/4-in. mercury is included in the data, but the entropy value at this pressure is carried only to a temperature of 150° F. A pressure value of 10 psi is the lowest pressure plotted through the temperature range of 0° F to 1,200° F.

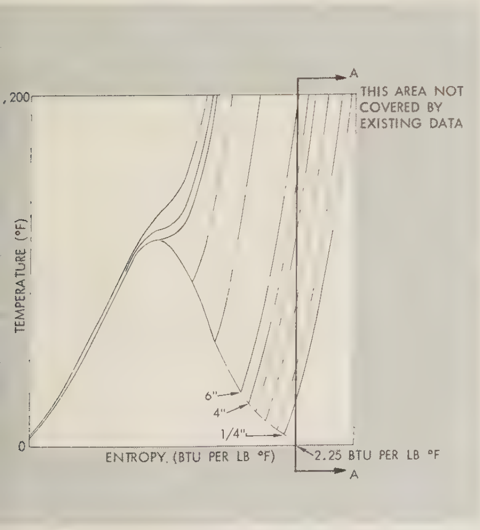


Fig. 1—The temperature-entropy diagram, shown here in basic outline, does not include data covering information on low pressure, superheated water vapor for a temperature range of from 0°F to 1,200°F. For purposes of the problem, the T-S diagram is to be extended in the direction indicated by the arrows *A-A*.

Problem

The problem is to determine property (entropy) values for superheated water vapor at low pressures and elevated temperatures by extending the existing temperature-entropy diagram. The required temperature range is to be from 0° F to 1,200° F. The pressure range should include pressures as low as 1/4-in. mercury.

To extend the T-S diagram, the following initial assumptions can be made:

- The properties of superheated water vapor may be established using perfect gas laws
- The change in entropy occurs in an isolated system and is therefore reversible
- The change in entropy occurs in a non-flow process.

The development of the needed temperature-entropy data will require the application of thermodynamic principles and calculus to plot the T-S diagram extension. The plot will show the manner of variation of the properties and indicate where interpolation is necessary.

The solution to the problem will appear in the January-February-March 1960 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Bibliography

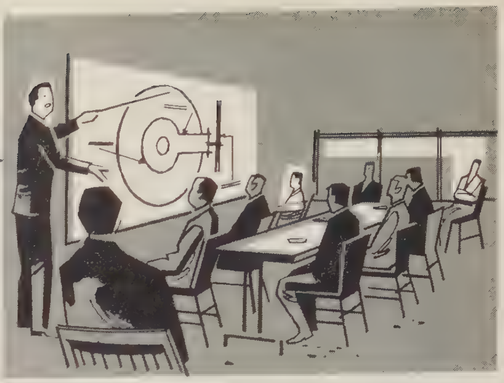
Literature useful in the solution of this problem includes the following:

KEENAN, J. H., and KEYES, F. G., *Thermodynamic Properties of Steam* (New York: John Wiley and Sons, Inc., 1951).

MOYER, J. A., CALDERWOOD, J. P., and POTTER, A. A., *Elements of Engineering Thermodynamics* (New York: John Wiley and Sons, Inc., 1941), pp. 81-2.

The problem presented here resulted from the question "What is the effect of atmospheric vapor on the charge inducted into the cylinder of an internal combustion engine?" which arose during a discussion period in an engine design class at G.M.I. To answer the question required the use of a temperature-entropy diagram and an application of low pressure, superheated water vapor knowledge to the exhaust products of an internal combustion engine. Data presented by the T-S diagram, however, did not include information for superheated water vapor at the high temperatures and low pressures usually encountered in an internal combustion engine. It was required, therefore, that thermodynamic principles be applied to extend the temperature-entropy diagram to provide the information desired.

Technical Presentations by GM Engineers and Scientists



The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers and scientists, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers and scientists to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Technical Center, P. O. Box 177, North End Station, Detroit 2, Michigan.

The following GM personnel made recent technical presentations.

Automotive Engineering

Peter Ashurkoff, project engineer, GM Engineering Staff, before the semi-annual meeting of the American Society of Mechanical Engineers, St. Louis; title: Research on Charge Stratification of Four-Stroke-Cycle Spark-Ignition Engines.

Joseph B. Bidwell, head, Engineering Mechanics, GM Research Laboratories, before the Indiana Editor and Publisher Highway Traffic Safety Seminar, Indianapolis; title: Electronics and Vehicular Safety.

A. E. Fyffe, patent engineer, AC Spark Plug Division, Milwaukee plant, before 5th grade students of Cumberland School, Whitefish Bay, Wisconsin; title: A History of the Automobile.

C. D. Harrington, administrative engineer, Oldsmobile Division, before the Portland, Michigan, Kiwanis Club; title: Styling of a New Car.

George W. Onksen, staff engineer, Guide Lamp Division, before the Automobile Manufacturers Association Committee on Engineering and Vehicle Inspection, Detroit; title: The 7-Inch, Type 2 Headlamp.

Raymond E. Seekins, senior project engineer, Harrison Radiator Division, before the National Automotive Radiator Service Association, Philadelphia; title: The Development of a Radiator.

From Chevrolet Motor Division: **Raymond E. Dunn**, assistant staff engineer, before the Quality Bakers of America Cooperative, Inc., Detroit; title: Chevrolet Truck Design, Testing, and Service Problems, and **Emmet C. Moynihan**, resident engineer, before the Syracuse, New York, section of the Society of Automotive Engineers; title: A Carriage for Milady.

From the General Motors Proving Ground: **Thomas E. Miller**, assistant head, Engineering Test Department, before auto mechanics teachers, Flint, Michigan, title: General Motors Proving Grounds, and **Hugh W. Larsen**, senior project engineer, before students of General Motors Institute, title: Vibration Problems in Automobile Structures and Drivelines.

Ralph H. Bertsche, head, Electrical Department, GMC Truck and Coach Division, served as representative for the Automobile Manufacturers Association at the Permanent International Bureau of Automotive Manufacturers meeting, Stockholm, Sweden, and at the Technical Committee meeting of the P.I.B.A.M., Rome, Italy. He also was a U.S. delegate to the International Commission on Illumination meeting, Brussels, Belgium.

S.A.E. Summer Meeting Atlantic City, New Jersey

At the S.A.E. annual summer meeting, Atlantic City, June 14-19, one session, under the chairmanship of **Nelson E. Farley**, staff engineer, Chevrolet Motor Division, was devoted to car safety. Four papers were presented at this session which had as its general title "The Safety The Motorist Gets." GM personnel who co-authored papers and made presentations were as follows: **Philip O. Johnson**, engineer in charge, Physical Testing Laboratory, Fisher Body Division, title: The Automobile Body; **Newell H. McCuen**, staff engineer, Chevrolet Motor Division, title: The Chassis; **Paul Fair**, Buick Motor Division, title: Electrical Accessories; and **Kenneth A. Stonex**, assistant director, GM Proving Grounds, title: Overall Car Appraisal.

Other GM personnel who made presentations at the S.A.E. summer meeting included: **Robert E. Harvie**, metallurgist, Chevrolet Motor Division, title: Steel—By Slipstick or By Slapstick; **Donald H. McPherson**, staff engineer, Chevrolet Motor Division, title: Engine Cooling and Passenger Car Styling; **William C. Edmundson**, staff engineer, Delco-Remy Division, title: Trends in Truck and Bus Electrical Equipment; **Robert R. Batson**, staff engineer, Cadillac Motor Car Division, Cleveland Ordnance Plant, discussion on the paper "Mobility for the Ground Soldier;" **Jerar Andon**, project engineer, GM Engineering Staff, title: Identification and Characteristics of Rumble and Thud; and **E. E. Nelson**, project engineer, and **C. E. Scheffler**, assistant engineer in charge, Power Development Group, GM Engineering Staff, title: High Compression—Is It Worth It?

Bearings

Personnel from GM Research Laboratories who made presentations before the national A.S.M.E. Design Engineering Conference, Philadelphia, were: **Donald F. Hayes**, research engineer, title: Design Curves for Journal Bearing, and **Arnold O. De Hart**, senior research engineer, title: Which Bearing and Why.

Personnel from New Departure Division who appeared before engineers of the Turbo Division, Sundstrand Machine Company, Denver, Colorado, were: **A. J. Gentile,** research metallurgist, title: Metallurgical Characteristics of Ball Bearings; **Robert J. Valentine,** supervisor, aircraft applications, title: High Speed, High Temperature Ball Bearing Developments; **Gordon J. Clark,** research chemist, title: Ball Bearing Lubrication.

Ceramics

W. E. Hauth, research scientist, AC Spark Plug Division, before the Flint, Michigan, sub-section of the American Chemical Society; title: Ceramics, A New Science.

Richard H. Singleton, senior experimental metallurgist, Allison Division, before the High Temperature Inorganic Refractory Coatings Working Group Meeting, University of Dayton; title: Ceramic Materials Research Status.

Karl Schwartzwalder, director of research, AC Spark Plug Division, introductory remarks before the annual convention of the American Ceramic Society, Alumina Symposium, Chicago, and narrator at the DuPont Development Conference, Wilmington, Delaware.

Electrical Engineering

Delco Radio Division engineering personnel who recently made presentations include: **E. R. Buehler,** electrical technician, before members of the Kokomo, Indiana, Amateur Radio Club, title: Effective Use of VHF Transmitting and Receiving Equipment; **Frank L. Hughes,** supervisor, field services, before electronic teachers of Massachusetts, Fitchburg, title: Fundamentals of Transistors, and before the Kokomo, Indiana, Lions Club, title: Transistors and Stereophonic Sound; **J. R. Snead,** junior engineer, before students of Kokomo, Indiana, High School, title: High Fidelity and Sound; and **R. H. Wright,** service engineer, before the science class of Monterey, California, Union High School, title: Fundamentals of Transistors.

Guided Missiles

The following engineering personnel of AC Spark Plug Division's Milwaukee, Wisconsin, plant made recent presentations on guided missiles and inertial guidance systems.

Raymond Berg, head, general systems engineering, before the Menomonee Falls, Wisconsin, Kiwanis Club; title: Missiles.

Robert Budyak, senior project engineer, before the Milwaukee Astronomical Society; title: Missiles in Flight.

Paul Larson, chief engineer, Thor missile program, before the Oconomowoc, Wisconsin, Rotary Club; title: Understanding the Space Age.

D. P. LeGalley, scientific staff consultant, before the Allis-Chalmers Engineering Society; title: Missile Talk.

Richard Roth, reliability engineer, before the Milwaukee Elks Club; title: Missiles.

Jack Schmidt, project engineer, before the Whitefish Bay, Wisconsin, Men's Club; title: The Soviet Challenge: Missiles, Technology, and Education.

C. J. Smittkamp, administrative engineer, before the Civic Organization of Young Business Executives; title: Reliability Considerations in the Development and Production of Missile Guidance Systems.

G. Kleinhesselink, systems engineer, and **J. F. Shea,** director, Advanced Systems Research and Development, provided guidance for the special lecture series for guided missile programs sponsored by the Air Force Institute of Technology, University of Michigan.

Manufacturing

Robert M. Critchfield, vice president in charge, GM Process Development Staff, before the Industry Water Conservation Conference, Ann Arbor, Michigan; title: Industry's Stake in Water Conservation.

Gerald H. Cummings, section head, economics, General Motors Institute, before economics students of Flint, Michigan, Central High School; title: Automation and the Economy.

John B. Harrison, manager, Olathe, Kansas, plant, Delco-Remy Division, before the Kansas Engineering Society; title: Production Techniques.

Joseph O. McGinnis, Jr., faculty member, General Motors Institute, before the Saginaw, Michigan, Valley chapter of the American Institute of Industrial Engineers; title: Predetermined Method Time System.

Arthur B. Wright, staff methods engineer, GM Process Development Staff, before the eastern Michigan chapter of the American Association of Hospital Accountants, Detroit; title: Concept of Methods Engineering in a Manufacturing Organization.

Miscellaneous

Laverne M. Aurand, experimental metallurgist, AC Spark Plug Division, before the Millington, Michigan, Chamber of Commerce; title: History and Use of Metals.

C. A. Brown, administrative assistant, General Motors Institute, before the annual meeting of the American Society for Engineering Education, Pittsburgh; title: Engineers for a Dynamic World; and before the Institute in Technical and Industrial Communications, Colorado State University; title: Anatomy of Technical Reports.

Charles E. Drury, plant manager, Central Foundry Division, before a University of Illinois seminar composed of foundrymen; title: Orientation on Central Foundry Division.

Max Ephraim, Jr., locomotive section engineer, Electro-Motive Division, before the Association of American Railroads, Chicago; title: Comments on the Report of the Committee on Locomotives.

William L. Mitchell, vice president in charge, GM Styling Staff, before national representatives of press, radio, and TV, GM Technical Center, Warren, Michigan; title: High Heels and Automobiles.

From Allison Division: **George J. Clingman,** communications engineer, before the Arcadia, Indiana, Lions Club, title: Lockheed Electra Powered by Allison Prop-Jet Engines, and **Herbert L. Karsch,** project manager, before the American Rocket Society, San Diego, title: Evolution of Range Safety Philosophy Toward Over-Flying Inhabited Areas.

From Buick Motor Division: **Forest R. McFarland,** executive assistant chief engineer, before the Industrial Mathematics Society, Detroit, title: Experiences, Highly Loaded Gearing, and **Joseph D. Turlay,** director, power plant activities, before students of General Motors Institute, title: Home-Made Outboard Motor Design.

From Frigidaire Division: **H. E. Van Scoyk,** assistant chief engineer, before the American Home Laundry Manufacturers Association, Chicago, title: Engineering and Research Trends into the 1960's, and **C. H. Wurtz**, manager, Refrigerated Appliances Engineering Department, before the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Lake Placid, New York, title: Air Circulation Within the Freezing Compartments, Its Benefits and Problems.

From Harrison Radiator Division: **Charles C. Eckles**, director, research and development, before the American Institute of Chemical Engineers, Kansas City, Missouri, title: 1,500°F Liquid Metal Heat Exchanger Design Development Program, and **Willard O. Emmons**, engineer in charge, research—commercial products, before the American Welding Society, Niagara Falls, New York, title: The Brown-Harrison Blood Heat Exchanger.

Ordnance

GM personnel who made presentations before the American Ordnance Association, Combat and Tactical Vehicle Division, Detroit, were: **Hugh C. Kirtland**, chief engineer, transmission engineering, Allison Division, title: Track Vehicle Transmissions, and **James M. Heyne**, administrative engineer, Cadillac Motor Car Division, Cleveland Ordnance plant, title: Guide Lines for Combat Vehicles.

Quality Control

Leo J. Nartker, superintendent, Quality Control Section, Delco Products Division, before the Muncie, Indiana, section of the American Society for Quality Control; title: Linear Correlation.

M. L. Stratton, director of quality, AC Spark Plug Division, Milwaukee plant, before the 6th Industrial Clinic for Quality Control; title: Reliability—What Is It?

Research

Personnel from the GM Research Laboratories who made recent presentations included:

Denos C. Gazis, senior research scientist, before the U. S. Naval Research Laboratory's Solid State Seminar, Washington, D. C.; title: Surface Waves in Cubic Crystals.

C. F. Nixon, head, Electrochemistry Department; **David W. Hardesty**, research engineer; and **James D. Thomas**, senior research engineer, before the national meeting of the American Electroplaters Society, Detroit; title: Experiences with the Copper Chloride Modified Acetic Acid Salt Spray.

Donald E. Hart, assistant head, Special Problems Department, before the first annual Institute for Practical Research on Operations, University of Connecticut; title: Digital Computer and Its Practical Applications.

John R. Hunsberger, research engineer, and **Albert F. Welch**, head, Electronics—Instrumentation, before the Baltimore, Maryland, section of the A.I.E.E.; title: A Thickness Indicator for Electroless Plating.

John P. Danforth, senior research engineer, before the national meeting of the A.S.T.M., Atlantic City, New Jersey; title: Training Industrial Personnel in Radioisotopic Utilization.

Before the national meeting of the American Nuclear Society, Gatlinburg, Tennessee: **Willard D. Cheek**, and **Farno L. Green**, senior research physicists, titles: Factors Affecting the Relative Photon Emission from Low Energy Photon Sources and A New Unit for Measuring the Intensity of Low Energy Photon Sources; **Bernard J. Riley**, research chemist, and **Seward E. Beacom**, senior research chemist, title: Radiotracer Techniques Useful in Studying Leveling as an Electrodeposition Phenomenon.

1959 General Motors Conference for Engineering and Science Educators

Twenty-eight educators, representing 26 colleges and universities in the United States and Canada, attended the Eighth GM Conference for Engineering and Science Educators held in Detroit July 5 through July 17.

Co-hosts for the Conference, designed to acquaint educators with GM product, production, and research activities, were: **Charles A. Chayne**, vice president in charge of Engineering Staff; **Robert M. Critchfield**, vice president in charge of Process Development Staff; **Dr. Lawrence R. Hafstad**, vice president in charge of Research Laboratories; and **William L. Mitchell**, vice president in charge of Styling Staff. Co-ordinator of the Conference was **Kenneth A. Meade**, manager, Educational Relations Section, Public Relations Staff.

On July 6, the educators visited the Research Laboratories at the GM Technical Center. After opening remarks by **Dr. Hafstad**, presentations were made by **Dr. J. V. Laukonis**, senior research physicist; **Robert H. Kohr**, supervisor of vehicle dynamics; and **Roy S. Cataldo**, senior research engineer. **John M. Campbell**, scientific director, was chairman of the Research Laboratory's program.

Mr. Critchfield was host for the educator group on July 7 when it visited the Process Development Staff. During the program, presentations were made by **Charles A. Nichols**, technical assistant to the vice president; **Harry D. Hall**, director, Process Development Section; **Peter L. Fucinari**, superintendent, Machine and Project Shop; **Clarence Chambers**, superintendent, Process Development Staff Laboratories; and **David Salatin**, superintendent, Metal Casting Laboratories.

Louis G. Seaton, vice president in charge, Personnel Staff, was chairman of the evening session during which time the following members of his staff made presentations: **David F. Waggoner**, director, Salaried Personnel Placement; **Joseph E. Chope**, administrator, Committee for Educational Grants and Scholarships; and **Victor P. Mathews**, director, Salaried Personnel Section.

During the morning of July 8, the educators were guests of the Styling Staff with **Mr. Mitchell** as host. The educators participated in a "design workshop" during which they designed an automobile according to specifications they had previously chosen. Members of the Styling Staff who participated in this "workshop" were **Dr. Peter Kyropoulos**, technical director; **Stefan Habsburg**, assistant chief designer, Research Studios; **Donald Hoagg**, chief designer, Design Development Studio; and **Judson Holcombe**, research engineer.

In the afternoon, the group toured the Cadillac Motor Car Division with **James M. Roche**, general manager, as host. **Anthony G. De Lorenzo**, vice president in charge of Public Relations Staff, discussed GM public relations activities with the educators at the evening session.

On July 9, **Mr. Chayne** was host to the educators at the Engineering Staff and spoke on product engineering in GM. Other members of the Engineering Staff who made presentations were: **Kenneth E. Brooker**, assistant to the manager, Engineering Staff Activities; **Dr. James E. Boyce**, supervisor, Education and Training; **Maurice A. Thorne**, engineer in charge, Vehicle Development; **Lothrop M. Forbush**, assistant engineer in charge, Vehicle Development; **Thomas Scott**, assistant engineer in charge, Vehicle Development; **Von D. Polhemus**, engineer in charge, Structure and Suspension Development; **Gilbert K. Hause**, engineer in charge, Transmission Development; and **Stephen Kalmar**, executive assistant engineer in charge, Power Development.

Louis C. Lundstrom, director, GM Proving Grounds, addressed the group at the evening session and presented a movie on the activities of the Proving Grounds. The next morning the educators visited the Proving Ground at Milford, Michigan, and were given a tour of the laboratories and road system.

After the Proving Ground visit the group traveled to General Motors Institute. **Guy R. Cowing**, president and director of G.M.I. acted as host. Each educator then visited the area of the Institute that interested him for consultation with faculty members and students.

From July 13 through July 15 each educator was on a field assignment to a GM Division or Staff. On July 16 the educators were addressed by **John F. Gordon**, president, General Motors.

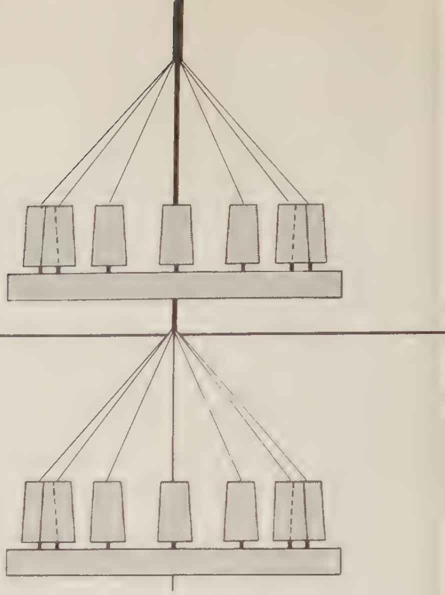
The educators met on the morning of July 17 for the closing general session of the Conference at the GM Technical Center. Dr. John E. Burchard, dean, School of Humanities and Social Studies, Massachusetts Institute of Technology, presented "Engineering Education and the Humanities," followed by a discussion period and the Conference adjournment.

Educators attending the eighth GM Conference for Engineering and Science Educators were (left to right on stairs): Harley J. Anderson, General Motors Institute; Myron L. Begeman, University of Texas; Donald F. Pierce, General Motors Institute; Oliver M. Stone, Case Institute of Technology; Loyal V. Bewley, Lehigh University; William H. Graves, University of Michigan; John E. K. Foreman, University of Western Ontario; Richard Bayer, Michigan College of Mining and Technology; Harold A. Bolz, The Ohio State University; E. A. Trabant, Purdue University; Carl M. Sneed, University of Missouri; J. Stuart Johnson, Wayne State University; George A. Jergenson, The Art Center School; Justin L. Glathart, Albion College; Prescott A. Smith, Massachusetts Institute of Technology; Leo C. Pigage, University of Illinois; George W. Bierly, The Pennsylvania State University; Roy A. Lindberg, University of Wisconsin; Robert I. Mitchell, University of Dayton; Theodore W. Cook, Central Michigan University. (Left to right at top): Philip B. Hughes, University of Toronto; George K. Tinetti, General Motors Institute; Richard C. Hill, University of Maine; Harry A. Auchter, Carroll College; Lewis D. Conta, Univ. of Rochester; Milton E. Raville, Kansas State College; W. Merle Carter, Univ. of Kentucky; Jay Doblin, Illinois Institute of Technology.

Solution to the Previous Problem:

Calculate the Burst Strength of a Braided Rubber Hose from Design Characteristics

To calculate the burst strength of a braided rubber hose requires the application of basic principles of force analysis. The approach used, however, is somewhat different from that usually used in analyzing hydraulic conduits because consideration must be given to the braided reinforcing material and the equipment used to fabricate the hose. This is the solution to the problem presented in the July-August-September 1959 issue of the GENERAL MOTORS ENGINEERING JOURNAL. Determination of the total burst strength for the braided hose having two layers of reinforcing material requires first the development of a general formula containing the variables affecting burst strength. The total burst strength was calculated to be *7,715 psi*.



The braided hose can be treated theoretically as the center section of a thin-walled vessel supported by the yarn of the reinforcing material which spirals about the longitudinal axis. Using this assumption, the force relationship on the center section can be established. This force relationship is comprised of forces acting on a plane perpendicular to the axis of the hose and forces acting on a plane containing the hose axis.

An internal pressure p applied around the inner circumference of the vessel produces a longitudinal stress S_L and a circumferential stress S_p (Fig. 1). For an equilibrium condition, the total stress must be equal to the total longitudinal pressure applied on the end of the vessel. The total stress is equal to

$$S_L\ (\pi Dt)$$

and the total longitudinal pressure is equal to

$$p\left(\frac{\pi D^2}{4}\right)$$

where

S_L = longitudinal stress (psi)
D = internal diameter (in.)
t = wall thickness (in.)
p = internal pressure (psi).

For equilibrium conditions, therefore,

$$S_L\ (\pi Dt) = F_L = p\left(\frac{\pi D^2}{4}\right) \qquad (1)$$

$$S_L = \frac{pD}{4t} \qquad (2)$$

where

F_L = total longitudinal force creating the total stress (lb).

The internal pressure acting around the inner circumference is balanced by the stresses acting on the wall of the vessel (section b-b', c-c', Fig. 2). For an equilibrium condition of forces acting in the Y direction (Fig. 2) the following relationship exists:

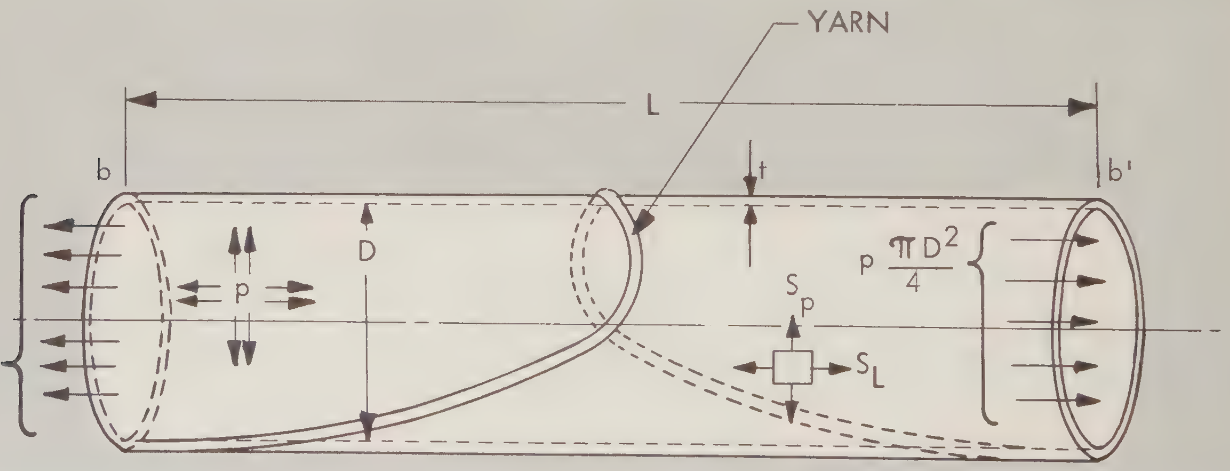


Fig. 1—The braided hose can be treated as the center section of a thin-walled vessel. An internal pressure p applied around the inner circumference of the vessel produces a longitudinal stress S_L and a circumferential stress S_p. For equilibrium conditions, the total stress $S_L \pi Dt$ must equal the total longitudinal pressure $p\pi D^2/4$. The length L is the lead of the helix formed by the braided reinforcing material. The internal diameter of the vessel is denoted by dimension D. The wall thickness of the vessel is denoted by dimension t.

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> **Formulas must be developed before calculations are made**

$$2S_ptL = 2F_p = 2\int_0^{\frac{\pi}{2}} p\,dA\cos\Theta \qquad (3)$$

where

S_p = circumferential stress (psi)
t = wall thickness (in.)
L = length of vessel (in.)
F_p = circumferential force component (lb)
p = internal pressure (psi)
dA = element of wall area (sq in.)
Θ = angle between the force acting on the element of wall area and the Y axis.

The element of area dA is equal to

$$dA = Lrd\Theta = d\Theta\left(\frac{DL}{2}\right)$$

where

$rd\Theta$ = finite length of arc.

Equation (3), therefore, becomes

$$S_p = \frac{pD}{2t}\int_0^{\frac{\pi}{2}} \cos\Theta d\Theta$$

and

$$S_p = \frac{pD}{2t} \qquad (4)$$

A comparison of equations (3) and (4) gives

$$F_p = \frac{pD}{2t}(tL)$$

or

$$F_p = p\left(\frac{DL}{2}\right). \qquad (5)$$

A comparison of equations (2) and (4) shows that

$$\frac{S_p}{S_L} = 2,$$

which means that the circumferential stress S_p is twice as large as the longitudinal stress S_L.

The preceding relationships can now be applied to determine the force relationship of the braided reinforcing material.

Referring to Fig. 1, the length L is also the lead of the helix formed by the braided reinforcing material. From Fig. 3-left, this length is equal to

$$L = \frac{\pi D}{\tan\alpha} \qquad (6)$$

where

D = diameter of the braid*
α = braid angle.

The force components in the braided reinforcing material are comprised of a tensile force R in the yarn, the longitudinal force component F_L, and the circumferential force component F_p (Fig. 3-right).

If the value for the length L as given in equation (6) is substituted into equation (5), the following relationship exists for the circumferential force component F_p:

$$F_p = p\left(\frac{\pi D^2}{2\tan\alpha}\right). \qquad (7)$$

Referring to Fig. 3-right, the tangent of the braid angle α is equal to:

$$\tan\alpha = \frac{F_p}{F_L}. \qquad (8)$$

Substituting into equation (8) the values for F_p and F_L given in equations (7) and (1) gives the following relationship for tan α:

$$\tan\alpha = \frac{p\left(\dfrac{\pi D^2}{2\tan\alpha}\right)}{p\left(\dfrac{\pi D^2}{4}\right)}. \qquad (9)$$

Using this relationship, the angle α can be obtained as follows:

$$\tan^2\alpha = 2$$

$$\tan\alpha = \sqrt{2}$$

$$\alpha = 54°44'.$$

Since all of the preceding calculations have been based on conditions of equilibruim, the angle α just calculated becomes the angle of equilibrium. This angle was defined in the problem as the braid angle which permits neither expansion nor contraction under pressure, assuming that the reinforcing material has no stretch and that there is no appreciable wall thickness.

The next step in the solution is to develop a formula for the burst strength of a braided hose.

First, consider a length of braided hose in which the yarns have adopted the angle of equilibrium with the longitudinal axis of the hose. If the hose is subjected to an internal pressure so that it is just at the point of bursting, the burst pressure p_b can be calculated as follows. From Fig. 3b:

$$F_L = R\cos\alpha = p_b\left(\frac{\pi D^2}{4}\right) \qquad (10)$$

$$F_p = R\sin\alpha = p_b\left(\frac{DL}{2}\right) \qquad (11)$$

where

p_b = burst pressure (psi)
R = tensile force in the yarn (lb).

Solving equations (10) and (11) for burst pressure gives:

$$p_b = \frac{4R\cos\alpha}{\pi D^2} \qquad (12)$$

$$p_b = \frac{2R\sin\alpha}{DL} \qquad (13)$$

In equations (12) and (13) the value for R, the tensile force in the yarn, can be replaced by either of the following expressions:

$$T_SN \text{ or } T_EEN$$

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*The letter D can be used to denote both the internal diameter of the thin-walled vessel and the braid diameter, since the thickness of the vessel and the braid is considered negligible when compared to the inside diameter of the vessel.

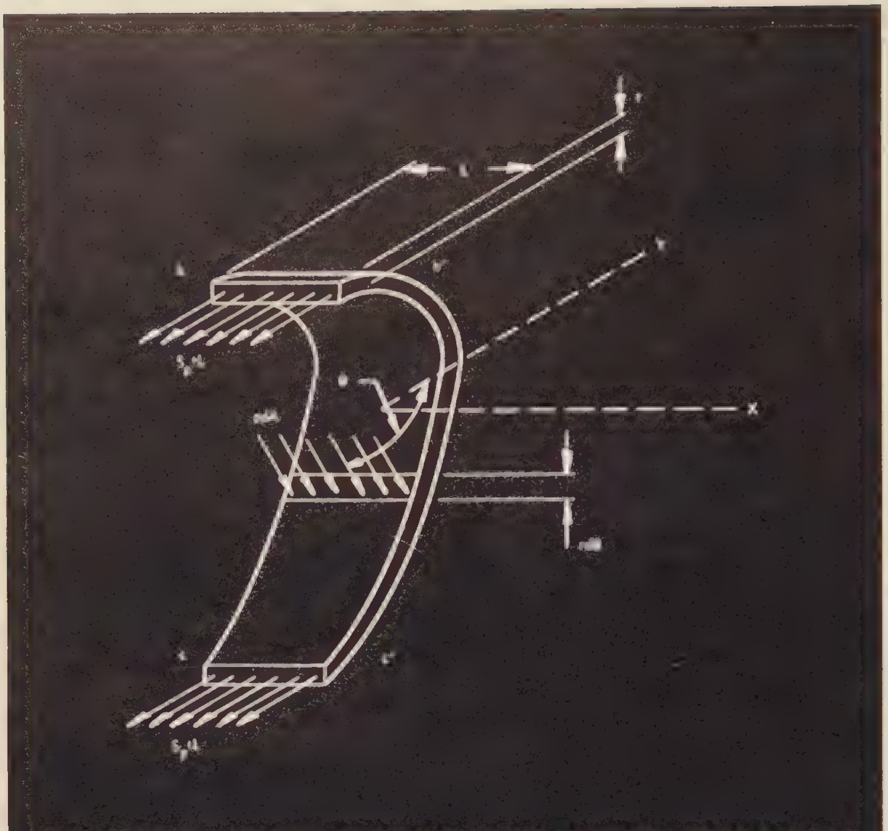

Fig. 2—Shown here is an elemental section (*b-b'*, *c-c'*) of the thin-walled vessel of length *L* and thickness *t*. For conditions of equilibrium, the internal pressure acting around the inner circumference of the wall, S_ptL, must be balanced by the stresses, pdA, acting on an elemental wall area of the vessel. Angle θ is the angle between the force acting on the element of wall area and the *Y* axis.

where

T_S = maximum tensile strength of one strand of yarn

T_E = maximum tensile strength of one yarn

E = number of yarns forming one strand

N = total number of carriers.

From the preceding definition of terms, therefore

$$T_SN = T_EEN.$$

Substituting the values T_SN and T_EEN for R in equations (12) and (13) gives the following series of relationships.

From equation (12):

$$p_b = \frac{4T_SN\cos\alpha}{\pi D^2} \tag{14}$$

or

$$p_b = \frac{4T_EEN\cos\alpha}{\pi D^2}. \tag{15}$$

From equation (13):

$$p_b = \frac{2T_SN\sin\alpha}{DL} \tag{16}$$

or

$$p_b = \frac{2T_EEN\sin\alpha}{DL}. \tag{17}$$

It was stated in the problem that the distance L between two equivalent positions of a strand equals the lead of the braid. Also, the number of picks per inch P between two equivalent positions of a strand is equal to half the number N of carriers. From this, the following equations are established:

$$P = \frac{\frac{1}{2}N}{L} = \frac{N}{2L}$$

or

$$L = \frac{N}{2P}$$

where

P = picks per inch

N = number of carriers in a deck

L = lead of the braid.

Substituting this value for L into equation (17) gives the following value for burst pressure:

$$p_b = \frac{4T_EEP\sin\alpha}{D} \tag{18}$$

where

D = hose diameter at point of burst (in.).†

Equations (14) and (16) are equivalent and are used by hose designers to calculate the burst pressure of a braided rubber hose having an angle of equilibrium of 54°44′.

If a hose is braided at angles less than the equilibrium angle of 54°44′, it is assumed that the hose will increase in diameter until the braid reaches the angle of equilibrium before the hose bursts. This increased value of the diameter d of the hose can be expressed by the following relationship:

$$D = \frac{d(\sin 54°44')}{\sin\alpha_1} \tag{19}$$

where

d = mean diameter of the reinforcing material in the hose before pressure is applied

α_1 = actual angle of braid before pressure is applied.

It is obvious that at an equilibrium angle of 54°44′, $D = d$.

Substituting the value for D as expressed in equation (19) into equations (18) and (15) gives the following equations for burst pressure. From equation (18):

$$p_b = \frac{4T_EEP\sin\alpha_1}{d} \tag{20}$$

From equation (15):

$$p_b = \frac{4T_EEN\cos\alpha\sin^2\alpha_1}{\pi d^2\sin^2\alpha} \tag{21}$$

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†Since the internal diameter of the thin-walled vessel is considered equal (for all practical purposes) to the diameter of the braid, the letter D also can be used to denote the hose diameter at point of burst, since the hose at the point of burst will assume the angle of equilibrium regardless of its original diameter.

or

$$p_b = \frac{1.1\,T_E E N \sin^2 \alpha_1}{d^2}. \qquad (22)$$

If equation (20) is to be used to calculate the bursting strength of a braided hose having a braid angle considerably different from the angle of equilibrium, it is necessary to correct the number of picks per inch P in this equation to correspond to the picks per inch at burst. This can be done by calculating D and L from equations (19) and (6), respectively, and then applying these calculated values in equation (18).

Using the preceding relationships, the burst strength for the braided hose having the specific characteristics described in the problem now can be calculated. To determine the total burst strength, it is necessary to calculate the burst strength for each reinforcement layer.

First Reinforcement Layer

The number of carriers N used to apply the first reinforcement layer was given as 24. Also, the picks per inch P_1 were given as 20.5. With this information the lead L can be calculated from the following relationship:

$$L = \frac{N}{2P_1} \quad \frac{24}{(2)\ (20.5)} = 0.585 \text{ in.}$$

The braid diameter d_1 before pressure is applied was given as 0.290 in. Knowing this value and also the lead allows the braid angle α_1 for the first reinforcement layer to be calculated by applying equation (6) as follows:

$$\tan \alpha_1 = \frac{\pi d_1}{L} = \frac{\pi(0.290)}{0.585} = 1.556$$

$$\alpha_1 = 57°16'.$$

Also,

$$\cos \alpha_1 = 0.54073$$

$$\sin \alpha_1 = 0.84120.$$

The tensile strength T_{E1} of the yarn used in the first reinforcement layer was given as 21.0 lb. Also, the number of yarns E_1 forming one strand was given as one. Substituting the given values for T_{E1}, E_1, N, and d_1 and the calculated values for L and α_1 into equation (22) allows the burst strength p_{b1} for the first reinforcement to be calculated as follows:

$$p_{b1} = \frac{1.1(21.0)\ (1)\ (24)\ (0.84120^2)}{(0.290)^2}$$

$$p_{b1} = 4{,}663 \text{ psi.}$$

Second Reinforcement Layer

The same procedure is used to calculate the burst pressure p_{b2} for the second reinforcement layer.

$$L = \frac{N}{2P} = \frac{24}{(2)\ (13)} = 0.923$$

$$\tan \alpha_1 = \frac{\pi d_2}{L} = \frac{\pi\ (0.395)}{0.923} = 1.345$$

$$\alpha_1 = 53°22'$$

$$\cos \alpha_1 = 0.59669$$

$$\sin \alpha_1 = 0.80247$$

$$p_{b2} = \frac{1.1\ (14)\ (2)\ (24)\ (0.80247^2)}{(0.395)^2}$$

$$p_{b2} = 3{,}052 \text{ psi.}$$

The total burst pressure p_{bt}, therefore, is equal to 4,663 + 3,052, or 7,715 psi.

The burst pressure for each reinforcement layer also can be calculated by applying equation (20). This gives the following values:

$$p_{b1} = 4{,}990 \text{ psi}$$

$$p_{b2} = 2{,}958 \text{ psi}$$

$$p_{bt} = 7{,}948 \text{ psi.}$$

As a matter of interest, the actual burst pressure of a braided rubber hose having the specific design characteristics given in the problem was 7,600 psi.

Summary

Inland Division engineers have found that for braiding angles within ±2° of the equilibrium angle of 54°44′, equation (20) gives good correlation with the results obtained from actual pressure testing of the hose.

The majority of hose design work at Inland is related to high pressure hose

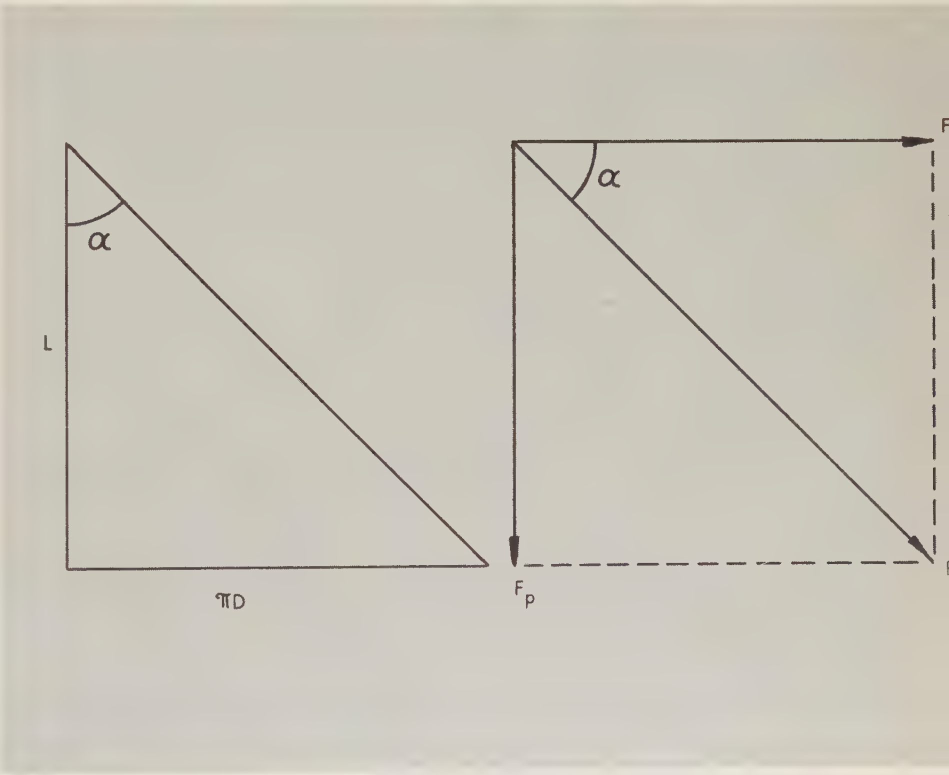

Fig. 3—The lead L of the helix formed by the braided reinforcing material (left) is equal to the circumference πD divided by the tangent of the braid angle α. The braided reinforcing material has force components (right) comprised of a tensile force R in the yarn, a longitudinal force compenent F_L, and a circumferential force compenent F_p.

design, where the reinforcement material has mostly low elongation under load. It is obvious that absolute agreement between calculated burst strength and actual results obtained from a pressure test on a piece of manufactured hose cannot be expected. This is because there are many other factors affecting the burst strength obtained by testing, factors such as rate of pressure rise, the efficiency of the braider, and elongation of the yarn at break.

Formulas using these additional factors have been derived, but have been found to have negligible results on accuracy. In addition, more calculation time is required. Recently, a digital computer has been utilized for calculating burst strength and provides a considerable saving in time when a number of calculations are necessary.

Regardless of the type of formula used, all equations derived in the preceding solution indicate that the following factors always should be considered to obtain the maximum burst strength under any condition:

- The braid diameter should be kept as small as possible
- The braid angle of the finished hose should be kept as close as possible to the equilibrium angle of 54°44′
- The reinforcing yarns should be designed for maximum tensile strength, along with low elongation under load.

A braided hose designed with these considerations in mind also will show low volumetric expansion under pressure. When the braided hose has to meet additional requirements, however, such as high flex life, fatigue resistance, or impulse resistance, a compromise is necessary to obtain the optimum design for a given application.

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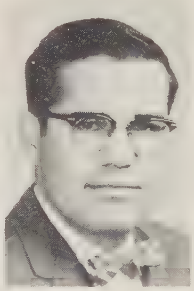

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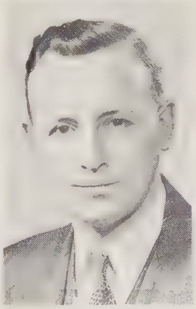

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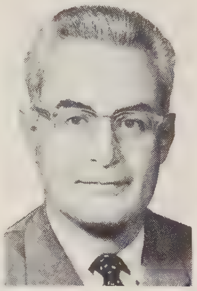

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He received the B.S. degree from Rice Institute and the M.S. degree in automotive engineering from University of Michigan. His technical affiliations include the Society of Automotive Engineers, American Ordnance Association, and the Coordinating Research Council. He has delivered a number of papers on gasoline and Diesel engines before technical societies and was cited for his work in the engine-fuel relationship field by the University of Michigan at its Centennial in 1953.

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(CP) Classroom problem
(Ed) Editorial—always appears on unnumbered inside front cover
(P) Portrait

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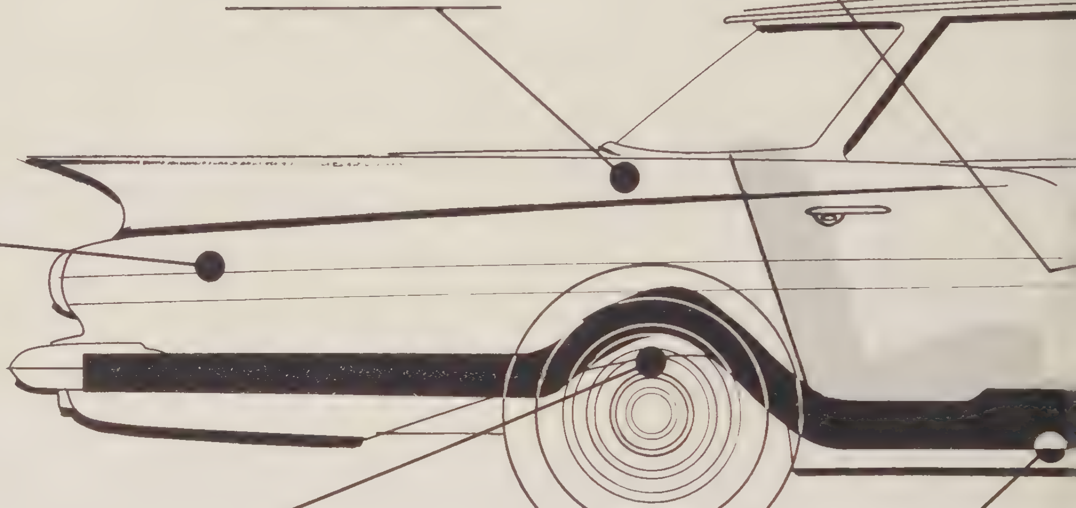

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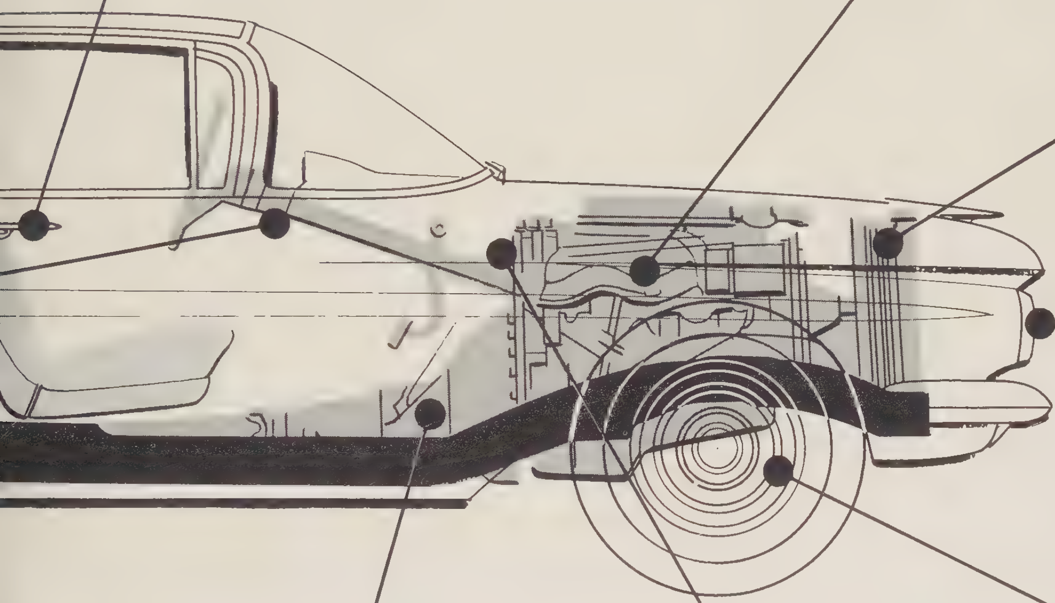

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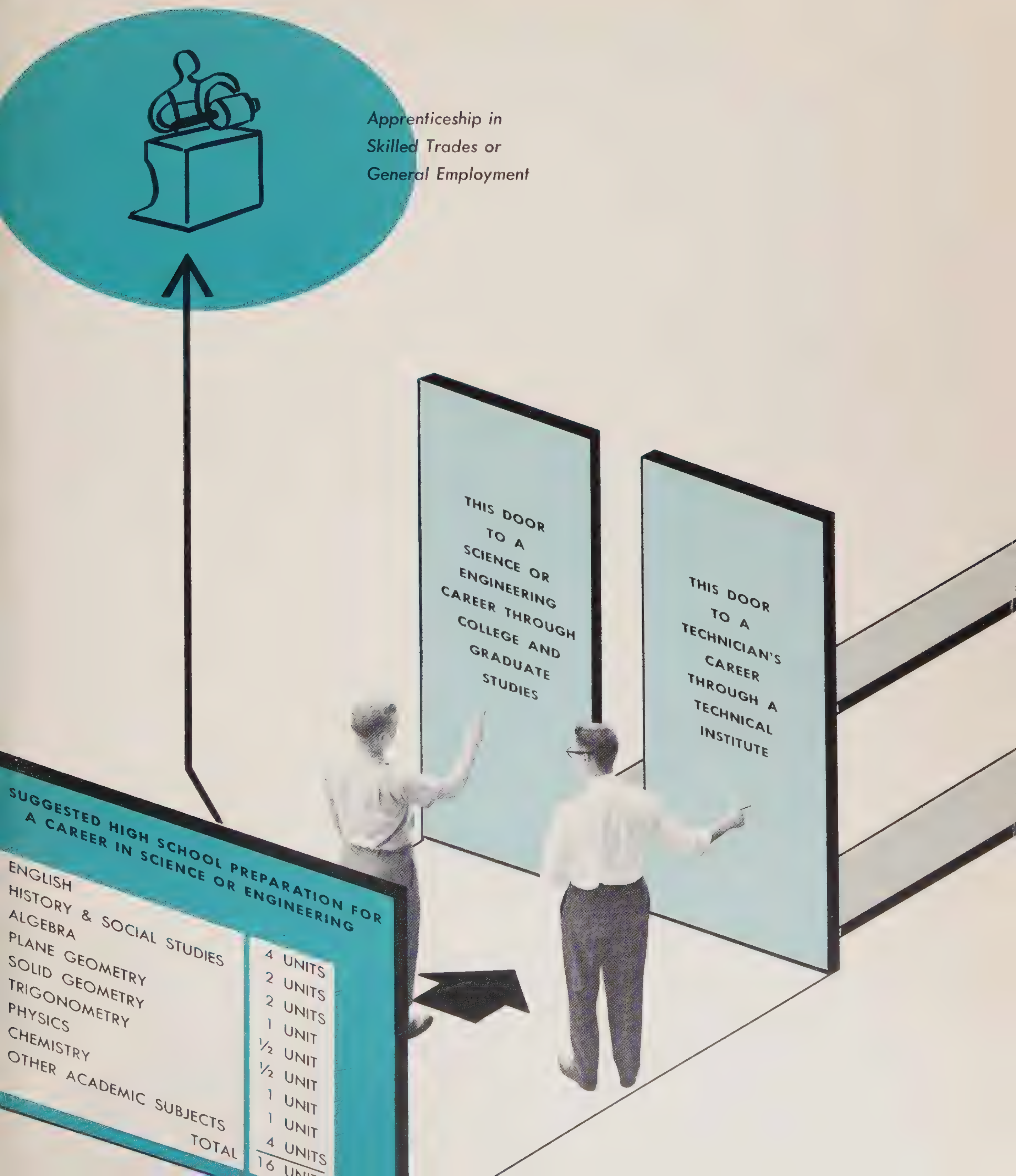

Apprenticeship in
Skilled Trades or
General Employment

THIS DOOR
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COLLEGE AND
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STUDIES

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TECHNICIAN'S
CAREER
THROUGH A
TECHNICAL
INSTITUTE

SUGGESTED HIGH SCHOOL PREPARATION FOR A CAREER IN SCIENCE OR ENGINEERING

ENGLISH	4 UNITS
HISTORY & SOCIAL STUDIES	2 UNITS
ALGEBRA	2 UNITS
PLANE GEOMETRY	1 UNIT
SOLID GEOMETRY	½ UNIT
TRIGONOMETRY	½ UNIT
PHYSICS	1 UNIT
CHEMISTRY	1 UNIT
OTHER ACADEMIC SUBJECTS	4 UNITS
TOTAL	16 UNI

INDUSTRY

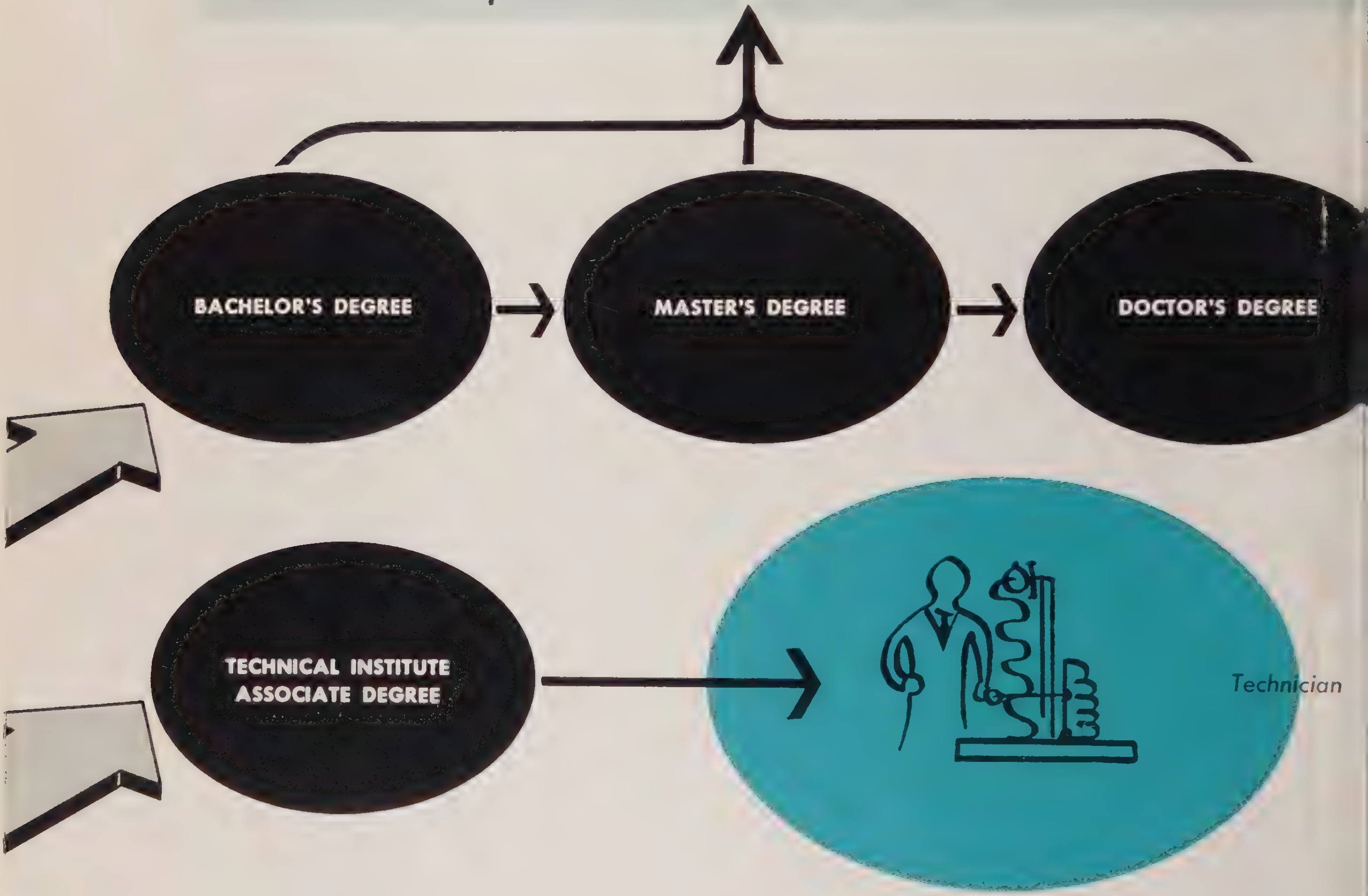
TYPICAL POSITIONS

ENGINEERING	RESEARCH
CHIEF ENGINEER	DIRECTOR OF RESEARCH
ASSISTANT CHIEF ENGINEER	DEPARTMENT HEAD
SENIOR ENGINEER	RESEARCH ASSOCIATE
PROCESS ENGINEER	RESEARCH ENGINEER
DESIGN ENGINEER	PHYSICIST
JUNIOR ENGINEER	CHEMIST
ENGINEER-IN-TRAINING	MATHEMATICIAN

EDUCATION

TYPICAL POSITIONS

COLLEGE	SECONDARY
DEAN	SCIENCE DEPARTMENT HEAD
DEPARTMENT HEAD	SCIENCE TEACHER
PROFESSOR	
ASSOCIATE PROFESSOR	
ASSISTANT PROFESSOR	
INSTRUCTOR	



BACHELOR'S DEGREE

MASTER'S DEGREE

DOCTOR'S DEGREE

TECHNICAL INSTITUTE ASSOCIATE DEGREE

Technician

This chart is intended as supplementary information for use by educators concerned with the counseling and guidance of students who may be thinking about careers in science or engineering. The chart shows the typical secondary school preparation needed, the higher educational steps required to assume positions in either industry or education, and some typical jobs. Copies of the chart for posting or reference purposes are available from: Educational Relations Section, Public Relations Staff, General Motors, Detroit 2, Michigan.

Please fold out this page. A chart, entitled "Doorways to Science and Engineering Careers," is presented for use as supplementary information in connection with student guidance activities.

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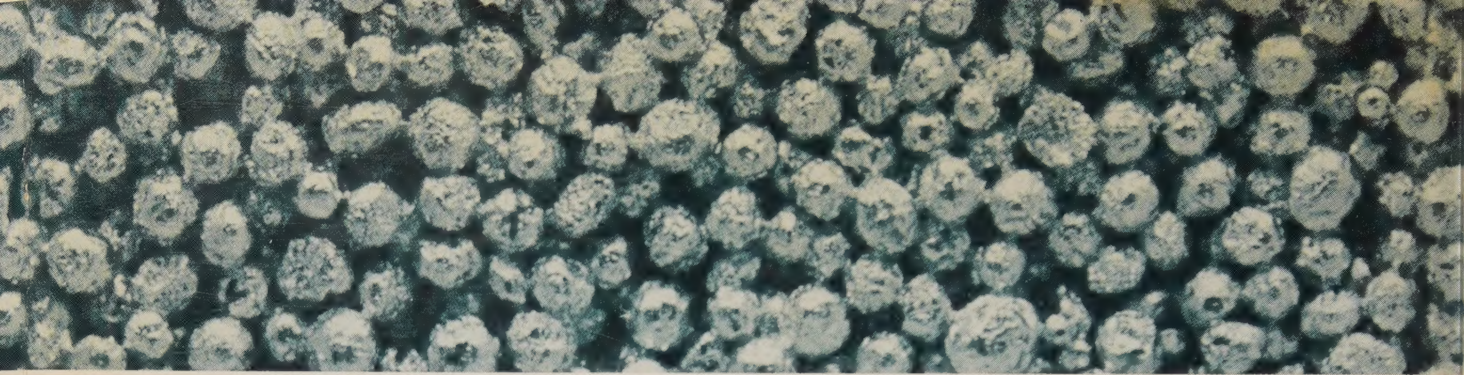

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